

The University of Chicago

THE ARTERIAL PATTERN
OF THE TUNICA MUCOSA OF THE
UTERUS IN MACACUS
RHESUS

AN EXPANSION OF A DISSERTATION SUBMITTED
TO THE FACULTY OF THE DIVISION OF THE BIO-
LOGICAL SCIENCES IN CANDIDACY FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF ANATOMY

1932

By
GARMAN HARLOW DARON

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THE ARTERIAL PATTERN OF THE TUNICA MUCOSA OF THE UTERUS IN MACACUS RHEBUS

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ELEVEN PLATES (FORTY-THREE FIGURES)

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INTRODUCTION

Since William Hunter proved the independence of the maternal and fetal circulation and demonstrated the presence of 'curling' arteries in the decidua of a 6 months' pregnant uterus, surprisingly little has been added to the knowledge of the vascular pattern in the tunica mucosa uteri. From his figures, which are the only records that have survived, it can plainly be seen that he was acquainted with the coiled

¹This research was made possible by a grant to The University of Chicago from the Rockefeller Foundation.

arteries within the decidua vera. However, from these figures there is no evidence that he understood the supply and distribution of these arteries or that he knew them to be present in non-pregnant uteri.

Farre (1859) in describing the blood vessels in the uterus says that the arteries take a remarkable corkscrew-like course through the myometrium to about halfway to the mucous membrane. Beyond this point they take a straighter course and finally run in parallel lines. When the arteries of the body of the uterus reach the mucous membrane they dip down between the glands and spread out in a network of capillaries. Farre makes no mention of spiral arteries in the tunica mucosa.

Leopold (1877) recognized the spiral arteries in the deep and middle portions of the tunica mucosa and describes them as breaking up into capillary nets superficially. In one specimen he found a spiral artery extending nearly to the surface epithelium.

Williams (1885) in writing on the circulation in the uterus says that from the stratum vasculare in the myometrium numerous branches are given off which run toward the mucous surface and in a direction perpendicular to that surface. These branches anastomose freely and terminate under the mucous surface in capillary loops.

Clark (1899) studied the circulation in the uterus in its relation to hemorrhage in cases of myoma uteri. He describes the external layer of the myometrium as being traversed by many arteries coursing in a direction concentric with the peritoneal surface. From the innermost of these circular arteries, "branches are given off at right angles which penetrate the inner muscular layer, supplying it with numerous anastomosing nutrient vessels, and finally terminate in a rich capillary supply to the endometrium."

Freund ('04), who was also working on pathological material, presents figures from a few injected uteri which show spiral arteries in the mucous membrane. However, he agrees with Farre that the arterial pattern is based on the pattern of the glands.

Sampson ('11), likewise interested in the blood supply of uterine myomata, briefly describes the circulation in the normal uterus. His descriptions agree with those mentioned above but his figures do not show the arterial pattern in the mucous membrane. In his injections of the venous system the injection mass is clearly seen in the mucous membrane (compare p. 390).

Saito ('26) has been the first to make a study of the cyclic changes in the blood vessels of the endometrium. He injected India ink into the uterine arteries of extirpated human uteri. He describes the cyclic changes in the blood vessels of the endometrium as follows: First, in the proliferative phase the arteries and veins course parallel to the uterine glands and perpendicular to the surface epithelium. The capillaries form a dense network in the superficial layer. The individual capillaries are straight and generally run parallel to the surface epithelium. In the middle zone of the endometrium this network of anastomosing capillaries closely surrounds the uterine glands with the long axis of the mesh parallel to the glands. In the basal zone the capillaries anastomose with those of the adjacent myometrium. Second, in the secretory phase the capillaries in the stratum compactum are dilated and the capillary meshwork is spindle shaped. In the stratum spongiosum the capillary meshwork is irregular due to the irregular form of the glands. There are varicose swellings of the veins between the stratum compactum and spongiosum and abrupt dilations of the veins in the latter zone. He does not mention the sinuosity of the arteries or their extent in the endometrium. However, in a diagram of the blood vascular pattern he shows them to be somewhat tortuous and that they extend through three-quarters of the endometrium where they suddenly branch into a number of capillaries in a fountain-like fashion. He presents this as the condition of the arteries in both the stage of proliferation and the stage of secretion.

Bohnen ('27), also working with human material, concludes that the coiled arteries of the endometrium extend only

through the basal zone of the mucous membrane and regards them as satisfactory landmarks for detecting the extent of tissue loss during menstruation. Bartelmez ('31), however, figures a spiral artery of the human uterus from the twenty-third day of the cycle, that extends from myometrium to surface epithelium. More recently he (Bartelmez, '33) has described the arteries in the necrotic zone of the menstruating mucous membrane.

In the last few years several studies have been made on the histology of the uterine blood vessels both in normal and pathological uteri. They have dealt, however, almost exclusively with the vessels of the myometrium. The 'Polster' of the intima of the arteries in the myometrium as described by Bucura ('03), Joachimovits ('28), Wiegand ('30), and others, may be of great importance in the control of the blood flow to the mucous membrane in various physiological and pathological conditions. Keiffer ('33 a and b) in a study of the morphological mechanism of menstruation considers the veins to be the structures of first importance. He has described regional modifications of the veins in the myometrium which he calls 'venous hearts.' These are valvular and contractile modifications of the venous walls. He believes that their action can account for all the vascular changes in the uterus such as the premenstrual congestion and the control of the loss of blood during menstruation. He does not seem to have observed arteries in the mucous membrane.

In summarizing this review of literature it must be said that information concerning the vascular pattern of the mammalian endometrium is very meager and that practically nothing is known concerning the changes of the vessels of the endometrium throughout the menstrual cycle. Since menstruation is fundamentally a vascular phenomenon a thorough description of the vascular pattern of the mucous membrane throughout the menstrual cycle would undoubtedly aid in the interpretation of this phenomenon. Such a description of the arterial pattern in *Macacus rhesus* is the province of this paper.

I owe much to Professor Bartelmez for his suggesting the problem and for his most generous help throughout the course of this study. Information concerning the ovaries of our animals was generously given by Dr. N. L. Hoerr and Prof. G. W. Corner. I am also indebted to Profs. R. R. Bensley, P. R. Cannon and P. Kyes for valuable suggestions in matters of technique.

MATERIAL AND METHODS

There are some outstanding difficulties involved in the study of the vascular bed of the mucous membrane of the uterus. This may account for the sparsity of information in the field. First, it is difficult to obtain satisfactory injections of the vascular bed in the mucous membrane. Second, the factor of great variability in the structure of the entire mucous membrane necessitates a large number of seriated specimens and until recently no satisfactory means of seriation was known. Third, in the use of post-operative or post-mortem material there are vascular changes the exact nature of which is unknown. And fourth, in the case of human material there is the difficulty of obtaining material, all features of which can be implicitly relied on as being normal. In this study some of these difficulties have been avoided. By using *Macacus rhesus* the amount of material is limited for the most part only by the available funds. By keeping the animals under observation for some time, adequate menstrual and ovarian histories could be obtained which makes possible proper seriation of the specimens. By a special process of injection and fixation it was possible to regularly obtain complete injections of the functional vascular bed and also to preserve the form of the vessels at the time of fixation.

Twenty-three specimens are considered in this study. With few exceptions these were adult animals when they were obtained by us. Most of them were probably nulliparous animals although no data were available concerning them prior to their arrival at our laboratory. In an effort to reduce the possible effects of psychic disturbances, especially

on the vascular system, the animals were handled as little as possible. Routine daily examinations were made of only external appearances that could be seen without disturbing the animals in the cages, which measured $6 \times 6 \times 18$ feet and were in a large well-ventilated sunny room. The data recorded concerned the variation in color of the sex skin and face; the amount of edema in the sex skin and adjacent regions; and the external show of blood from the vagina. On the basis of these records particular animals were chosen to be sacrificed at particular stages in the menstrual cycle.

The procedure that was finally adopted in the injection and fixation of the material was as follows: The animal was given 0.1 to 0.15 gm. of sodium amytal intraperitoneally; the exact quantity being roughly dependent upon the weight of the animal. Minimal doses were used to reduce the effects on the vasomotor system as much as possible. While the amytal was being absorbed an intravenous injection of an 8 per cent colloidal solution of mercuric sulphide was begun. This was done with a 5 cc. Pitkin syringe through a shank vein. The mercuric sulphide (Hille) is an almost non-toxic colloid and is a valuable agent for in vivo injections (Potter, '31). Sulphide solutions as dilute as 2 per cent have been found satisfactory; however, the more concentrated solutions are more desirable for vascular injections. The sulphide solution was injected at the rate of from 5 to 10 cc. per minute. The injection was timed so that the animal became completely relaxed soon after the intravenous injection was begun. The abdomen was then opened to facilitate subsequent manipulations and the borders of the wound were held together with hemostats. The sulphide injection was then continued until from 40 to 110 cc. had been injected. For adult animals 60 to 70 cc. proved to be very satisfactory. When the sex skin and the vessels of the conjunctiva became sufficiently dark the abdomen was quickly opened and 80 per cent alcohol poured onto the uterus. This was usually done while the injection was still going on. The alcohol had been previously chilled with carbon dioxide snow to about -80°C .

and consequently froze the tissue almost instantaneously. The ovaries were quickly clipped out, examined, and fixed in various solutions. The uterus was divided longitudinally by a cut either in a sagittal or in a frontal plane. One-half of the uterus was removed and placed in formol-chrom-sublimate solution; the other half was placed in 80 per cent alcohol at -10 to 20°C . The alcohol was allowed to come to room temperature very slowly by keeping the container surrounded with cotton. This procedure of freezing and fixing with cold alcohol has been found to preserve, more or less exactly, the functional form of the blood vessels (compare p. 385).

In studying the material it was the general practice to make transverse cuts through the two halves of the uterus at various levels and remove free-hand sections of the material of from 0.1 to 1.5 mm. in thickness. These were cleared in isosaphrol or benzyl benzoate and studied under the low power binocular microscope. By this procedure much of the arterial pattern can be worked out and recorded. Since the spiral arteries are very tortuous it was necessary to take rather thick sections of the tissue in order to get complete arteries. In such thick sections it was impossible to see the peripheral extent of the arteries or all of their branches, hence serial sections have been resorted to. It was found convenient first to clear a 1.0 to 1.5 mm. section of the tissue and record by means of a camera lucida the course of certain of the spiral arteries as completely as possible. This piece of tissue was then embedded and cut into serial sections 12 to $25\ \mu$ thick. Projection reconstructions were made of the further extent of the arteries and their branches. The reconstructions were made by superimposing camera lucida drawings of the sections on tracing paper, using the drawing of the whole mount as a check.

DESCRIPTION OF SPECIMENS

Before describing the endometrial arteries of the various specimens it will be well to describe briefly the general plan of arterial distribution in the uterus of *Macacus rhesus*. The

arterial supply and distribution in this species is much the same as in *Homo* as far as it is known in the latter. From the two lateral uterine arteries in the broad ligament many large branches are given off which penetrate the uterus. These arteries course in an arcuate fashion toward the midline between the outer and middle thirds of the myometrium. Since they do not branch as they enter the uterus but pass bodily into either the anterior or posterior wall, each of these arcuate arteries supplies one quadrantal segment of the uterus. They terminate near the midline in either of the two types of branches to be mentioned later or by anastomosing to some extent with their fellows from the opposite side. This anastomosis results in a complete vascular ring around the uterus in the substance of the myometrium. Since the arcuate arteries are large and highly coiled in the contracted uterus, this vascular ring forms a distinct zone in the myometrium. Along the course of each arcuate artery two types of branches are given off: first, large radial centripetal branches, and second, smaller peripheral branches. The latter type supplies the myometrium peripheral to the stratum vasculare. The centripetal radial arteries are somewhat tortuous at their origin but usually become rather straight and truly radial in their course through the inner half of the myometrium. They are usually branched, the branches arising at acute angles and continuing toward the endometrium in more or less parallel lines. Some of these radial arteries terminate in the myometrium while others continue into the mucous membrane. The latter type has very few and often no branches as it passes through the inner fourth of the myometrium. There are two distinct types of these endometrial arteries. The larger type is a very tortuous spiral artery that may extend to the surface epithelium in certain stages of the menstrual cycle. It will be referred to in this paper as the 'coiled artery.' In thin microscopic sections it appears as an 'arterial field' which consists of a limited area filled with numerous transverse and oblique sections of the artery surrounded by a dense stroma. The arterial field has

been misinterpreted by some workers as a section of a tuft of arteries. The appearance of a single coiled artery in section is shown in figures 17, 18 and 40. The second type of artery entering the endometrium is exceedingly small, only slightly coiled, and terminates in capillaries very soon after entering the mucous membrane (compare fig. 42). In the descriptions to follow this smaller type of endometrial artery will be designated as 'type II.'

The distribution of the specimens throughout the menstrual cycle is shown in the accompanying table. They will be described in three groups: first, uteri associated with ovaries showing histologic evidence of activity (fifteen cases); second, specimens without such ovarian correlation (six cases); and third, those which are at present incertae sedis (two cases).

DISTRIBUTION OF SPECIMENS		DISTRIBUTION OF SPECIMENS	
Day of cycle	Specimen number	Day of cycle	Specimen number
1	122	8	124
	127		132
	135		111
2	113	11	133
	121	13	116
	125	16	13
3	7	19	114
	15	21	3
	20	24	17
	128	26	123
4	12	27	115
	120	30	

Within the groups they are arrayed according to the number of days between the beginning of the last menstrual period and killing.

UTERI WHICH CORRESPOND TO THE SO-CALLED 'TYPICAL' CYCLE

Proliferative phase

Fourth day (no. 120); weight 3.18 kilos. This was an adolescent animal. On the morning of the fourth day of the

cycle there was no fresh blood showing externally; however, blood was detected in a vaginal lavage. Five hours later in another lavage, no blood could be seen macroscopically. The animal was injected and killed 1 hour later. An injection of 10 cc. of 8 per cent colloidal mercuric sulphide caused

MENSTRUAL RECORD OF NO. 120	
Duration of flow	Length of cycle
2	285 (Nov.-July)
2	23 (Aug.)
2	48 (Sept.-Oct.)
2	69 (Oct.-Dec.)
3	Killed fourth day (Dec. 24)

a temporary respiratory failure. In 25 minutes she had completely recovered so that the injection was continued. This time 75 cc. of the sulphide were injected in about 8 minutes without any detectable signs of physiological disturbances. The uterus was frozen with chilled 80 per cent alcohol and fixed in alcohol and 10 per cent neutral formalin according to the procedure outlined on page 354.

The left ovary contains a corpus luteum, measuring 4×3 mm., which belonged to the preceding cycle. The glands of the endometrium show a slight dilation in certain places in the basal zone suggesting an incomplete involution of a preceding pro gravid state (fig. 32). The endometrium varies in thickness from 3.8 to 2.8 mm. down to 1.0 mm. at the lateral angles.² It is very vascular; small veins and capillaries are present in great abundance throughout the entire mucous membrane. The coiled arteries are well filled with the sulphide. They are all very similar to the one reconstructed (fig. 1). They vary considerably in size but the majority are about 25μ in diameter. They do not extend to the surface epithelium and the radial myometrial arteries that supply them do not have the cone-shaped constrictions usually

² All measurements given in these descriptions, unless otherwise stated, were made on material fixed in chilled 80 per cent alcohol and stored in a mixture of equal parts glycerine and 95 per cent alcohol.

found in menstruating specimens (compare p. 391). In 8μ sections the epithelium is seen to be intact over almost the entire surface. In some places it is very well organized while in others the cells are very low and even absent in limited areas. Where the epithelium is best developed, there is a narrow subepithelial zone of closely packed stroma cells. The presence of this dense zone, the well-organized epithelium over most of the uterus and especially the thickness of the mucous membrane in the absence of reorganization, suggest that there had been little loss of tissue during the preceding menstruation. Many very small precapillary arterioles can be seen throughout the entire mucous membrane. There are relatively a large number of branches from the coiled arteries (compare fig. 1). Single, more or less straight, terminal, precapillary arterioles can, in some cases, be found slightly nearer the surface than those shown in the reconstruction, but in no case do they closely approach the surface epithelium. It seems improbable that the loss of tissue ever reached the level of the arterial fields during this last menstrual flow. Capillaries are present even in the superficial compact zone, but here they resemble small sinusoidal spaces rather than true capillaries.

MENSTRUAL RECORD OF NO. 124

Duration of flow	Length of cycle
1	78 (June–Aug.)
3	57 (Sept.–Oct.)
2	37 (Oct.–Nov.)
1	24 (Dec.)
3	Killed eighth day (Dec. 28)

Eighth day (no. 124); weight 3.52 kilos. This animal was first injected intravenously with 7 cc. of an 8 per cent colloidal solution of mercuric sulphide. Then 150 mg. of sodium amytal were injected intraperitoneally, and 30 minutes later 40 mg. more were given. After the lapse of another 5 minutes a little ether was administered to complete the anesthesia. An additional 85 cc. of the sulphide solution were then injected. The subsequent procedure was as outlined on page

354 with substitution of 10 per cent neutral formalin for the formol-chrom-sublimate solution.

Each ovary contains a corpus luteum of medium size. The one on the left measured 3.8×3.6 mm. and probably belonged to the previous cycle. There are no follicles in either ovary over 1.0 mm. in diameter. The endometrium varies in thickness from 2.2 to 2.8 mm. in the midline to about 1.3 mm. at the lateral angles (compare fig. 14). In thick free-hand sections the coiled arteries are very prominent in the basal half of the endometrium. In sections about 0.2 mm. thick, the greater part of four or five coiled arteries are usually seen in cross sections of one lateral half of the uterus. Six are indicated in the section shown in figure 37. They are all about the same size, the lumen being 35 to $42\ \mu$ in diameter. They arise from radial arteries in the myometrium of about the same size. In addition to the large coiled arteries extremely small arteries ($7\ \mu$ or less in diameter) can be seen entering the mucous membrane. These are the 'type II' arteries previously mentioned, which break into capillaries soon after entering the mucous membrane and directly supply only the basal zone (compare fig. 42). In thick, free-hand sections the coiled arteries are seen to extend one-third of the distance from myometrium to surface epithelium. In thin ($10\ \mu$) sections the corresponding arterial fields are confined to the same region. By considering the size and extent of the arterial fields one can form a rather accurate conception of the nature of the coiled arteries. They branch into rather straight terminal arterioles which can be traced but little farther than the middle of the endometrium; beyond this point only capillaries and veins are found. The coiled arteries in this specimen closely resemble those shown in figures 7 and 8. Along their course there are very few small branches. The lumen of the coiled arteries in the material fixed in chilled alcohol varies from 35 to $40\ \mu$ in diameter. In the material fixed in formalin the lumen is much smaller. Capillaries are abundant throughout the entire mucous membrane but are larger and more numerous just beneath the

surface epithelium. There are no large cavernous veins in the endometrium.

Eighth day (no. 132); weight 4.55 kilos. The procedure of injection, anaesthetization and fixation was as outlined on page 354 except that the mercuric sulphide used was a 2 per cent solution.

MENSTRUAL RECORD OF NO. 132

Duration of flow	Length of cycle
2	48 (Nov.-Dec.)
2	97 (Dec.-Mar.)
1	22 (Mar.-Apr.)
2	Killed eighth day (Apr. 22)

The left ovary contains a corpus luteum from the preceding cycle. Neither ovary contains follicles over 1.2 mm. in diameter. The endometrium varies in thickness from about 2.5 mm. in the midline to about 1.3 mm. at the lateral angles (compare fig. 15). In 12 μ sections arterial fields are prominent in the middle third but almost totally lacking in the basal third of the endometrium. The significance of this is made clear in the projection reconstruction of the typical coiled artery shown in figure 2 where it is seen to be closely coiled in the middle third but rather straight in the basal third of the endometrium. The coiled arteries vary considerably in size; the smallest ones are found in the lateral angles. The lumen of the largest of them is from 30 to 40 μ in diameter. The radial arteries in the adjacent zone of the myometrium are usually slightly smaller in diameter than the latter. Branches of the coiled arteries are common in the basal zone but rather rare in the middle third of the endometrium. They are usually 7 μ or less in diameter ('Br' fig. 2). The coiled arteries branch into precapillary arterioles slightly above the middle of the endometrium. These terminal branches leave the coiled mass of the artery and proceed straight toward the surface epithelium (fig. 2). They have lumina of 7 to 10 μ in diameter and end in capillaries 0.2 to 0.3 mm. from the surface epithelium. Weigert's

elastic tissue stain indicates the presence of elastic tissue in the walls of these terminal arterioles. In addition to the coiled arteries there are extremely small (7μ), type II, arteries in the basal zone of the endometrium. At least some of these do not arise as branches of the radial arteries which continue into the coiled arteries of the endometrium. This is significant (compare p. 393). In the superficial fifth of the endometrium there is a rich capillary network; in the rest of the endometrium the capillaries are smaller and fewer in number. There are no large cavernous veins in the endometrium.

Eleventh day (no. 111); weight 4.1 kilos. The routine procedure was followed in this case with the exception that 0.1 per cent heparin was added to the sulphide solution and ether was used as the anaesthetic.

MENSTRUAL RECORD OF NO. 111	
Duration of flow	Length of cycle
6	43 (July-Aug.)
3	27 (Sept.)
2	26 (Oct.)
3	23 (Oct.-Nov.)
4	24 (Nov.-Dec.)
4	22 (Dec.)
4	Killed eleventh day (Jan. 10)

The right ovary contains a large follicle (4.8 by 4.7 by 2.9 mm.) with cumulus and ovum. The germinal vesicle is somewhat eccentric. In addition the right ovary contains one, and the left two, corpora lutea from the previous cycles. The endometrium varies in thickness from 3.0 to 4.0 mm. down to 1.8 mm. at the lateral angles (compare figs. 3 and 16). In unstained sections of 0.1 to 0.3 mm. in thickness, the capillaries and veins appear larger than in the three previous specimens. The coiled arteries are prominent and the lumina are all from 30 to 35 μ in diameter; those in the lateral angles are somewhat smaller. They extend from the myometrium to about the middle of the mucous membrane (compare fig. 3). The radial myometrial arteries from which the coiled arteries

arise have the same average diameter as the latter, but contain less sulphide. There is a rather prominent venous plexus parallel to the surface between the basal and middle third of the endometrium. In 15μ sections a few precapillary arterioles are to be seen a bit nearer the surface than that in figure 3 but they never extend much beyond the middle of the mucous membrane. There are very few branches from the coiled arteries other than the terminal ones; none at all were found arising from the reconstructed artery. Type II arteries can be seen entering the endometrium from the muscle but are exceedingly small and soon break up into capillaries upon entering the mucous membrane. Capillaries are found throughout the latter but are especially prominent near the surface epithelium.

Progravid phase

Sixteenth day (no. 116); weight 5.45 kilos. This animal was first injected intravenously with a very small amount of 8 per cent colloidal mercuric sulphide containing 0.04 per cent heparin. The intravenous injection was interrupted and

MENSTRUAL RECORD OF NO. 116

Duration of flow	Length of cycle
2	45 (July-Aug.)
3	62 (Sept.-Oct.)
3	26 (Nov.)
3	30 (Dec.)
4	27 (Jan.)
2	Killed sixteenth day (Feb. 11)

sodium amytal was injected intraperitoneally. While the anesthetic was being absorbed the injection of the sulphide-heparin was continued until 115 cc. had been injected. The subsequent treatment was as outlined on page 354.

A bloody stigma was present on each ovary and sections show young corpora lutea. The endometrium varies from 3.8 to 4.3 mm. in thickness down to 2.5 mm. at the lateral angles (compare figs. 4 and 17). In unstained sections 0.2

to 0.3 mm. in thickness the most prominent features are the coiled arteries and large radial veins in the endometrium. The veins are straight and parallel. They are 20 to 35 μ in diameter. Irregular enlargements and large cross anastomoses of the veins are found in a position roughly between the basal and middle thirds of the endometrium. In 0.3 mm. sections the greater parts of six to eight coiled arteries are seen in a cross section of one-half of the uterus. In figure 17 three arterial fields can be plainly seen. These arteries are very tortuous basally (compare fig. 4) but occasionally a rather simple coiled artery may be found, usually located in or near the lateral angle. The size of the lumina varies from 15 to 40 μ and again the smaller ones are found in the lateral angles. The coiled portions extend from the myometrium to about the middle of the mucous membrane. However, in 15 μ sections their terminal ends can be traced considerably beyond this point as seen in the reconstruction (fig. 4). Their lumina are usually wider than those of the myometrial arteries from which they arise. Numerous very small type II arterioles enter the mucous membrane but their extent is very limited. A section showing both types of arteries as they enter the mucous membrane is reproduced in figure 42. Capillaries are abundant throughout the entire mucous membrane.

Twenty-fourth day (no. 3); weight 6.36 kilos. This animal was anesthetized with sodium amytal and then injected intravenously with 105 cc. of 8 per cent colloidal mercuric sulphide. Following this a post-vital injection of colored gelatine was given with hydrostatic pressure. After an attempt to inject the lymphatics, the entire uterus was removed and fixed in 10 per cent neutral formalin.

The left ovary contains a corpus luteum in the 'blossom' stage. The endometrium varies from 5.0 to 5.7 mm. in thickness down to 1.8 mm. at the lateral angles (compare fig. 19). In thick unstained sections the coiled arteries are very tortuous and extend nearly to the surface epithelium. In 15 μ sections their lumina are never over 25 μ in diameter which

is considerably smaller than in the arteries of other pseudo-pregnant specimens. This condition may be due to the technical procedure. In thin stained sections the arterial fields are seen to extend to within 0.3 mm. of the uterine lumen and single arterioles are as close as 0.15 mm. The terminal portion of a coiled artery is reproduced in figure 43. The artery is seen to be tortuous close to the surface epithelium. The terminal end of this and similar arteries are contracted and often there is no visible lumen. It seems most likely that this condition is due to the technique. The arteries

MENSTRUAL RECORD OF NO. 3

Duration of flow	Length of cycle
3	67 (Oct.-Nov.)
3	59 (Dec.-Jan.)
2	56 (Feb.-Mar.)
3	31 (Apr.)
3	79 (May-July)
4	67 (July-Sept.)
1	24 (Sept.-Oct.)
2	24 (Oct.)
3	26 (Nov.)
2	24 (Dec.)
3	25 (Jan.)
3	27 (Feb.)
2	Killed twenty-fourth day (Mar. 13)

are very similar to that shown in figure 5 (thirtieth day specimen) except that the convolutions are nearer the surface and the lumina are much smaller. Capillaries and large veins with extremely thin walls are abundant in the superficial part of the mucous membrane. In its lower two-thirds, where the glands are greatly dilated, the capillaries are very small and few in number.

Twenty-seventh day (no. 123); weight 5.0 kilos. This animal was given an intravenous injection of 40 cc. of 2 per cent colloidal mercuric sulphide. Ether was then administered and the abdomen opened. While an additional 15 cc. of the sulphide were being injected, chilled acetone was poured onto the uterus which was subsequently treated as outlined on page 354.

One ovary contains a corpus luteum in the 'blossom' stage. The uterus is unusually large. In 80 per cent alcohol it measured 30 mm. from side to side and 58 mm. from the external os to the vault of the fundus. This is to be compared with 18 to 23 mm. by about 40 mm. as determined from our other pseudopregnant specimens and from measurements given by Hartman ('32). The endometrium is 14.8 mm. thick over much of the corpus (fig. 20). At the lateral angles it is about 4 mm. thick. In thick sections the arteries are similar to that shown in figure 5 of the thirtieth day specimen except that they usually approach the surface more closely and often

MENSTRUAL RECORD OF NO. 123	
Duration of flow	Length of cycle
5	37 (Apr.-May)
4	39 (June)
3	24 (July)
3	86 (Aug.-Oct.)
2	33 (Oct.-Nov.)
3	28 (Dec.)
2	28 (Dec.-Jan.)
2	28 (Jan.-Feb.)
5	27 (Feb.-Mar.)
3	Killed twenty-seventh day (Apr. 8)

the general course of the artery is not straight toward the surface. There is great variation in the size of the coiled arteries. Some of them have a lumen of 120μ while others are not over 15μ . The larger ones have thicker walls than the smaller ones showing that the difference in size of lumen is an actual difference and not due, entirely at least, to the relative state of contraction or dilation of the vessels. Some of them maintain their large size close to the surface epithelium. Many arteries 75μ in diameter are found within 0.45 mm. of the surface epithelium. These large arteries near the surface always have thin walls. In a superficial zone about 0.4 mm. wide, the vessels are very large, often being 50μ in diameter. They give this zone a cavernous appearance in thin sections. The veins are not exceptionally

dilated and there are relatively few large cavernous transverse venous anastomoses.

Thirtieth day (no. 115); weight 4.55 kilos. This animal had been in our colony from June until November and during that time no menstrual flow was observed. On November 7th she bled freely from the vagina for 1 day. Twenty-nine days later she was killed. The routine procedure was followed in the preparation of the material (p. 354).

One ovary contained a corpus luteum in the 'blossom' stage with the stigma still prominent. The endometrium varies in thickness from 3.8 to 4.8 mm. down to 2.2 mm. at the lateral angles (compare figs. 5 and 18). In thick unstained sections the mucous membrane is seen to be very vascular. Veins and capillaries are very abundant and the arteries are very tortuous. The latter are rather uniformly 35 to 40 μ in diameter in the basal zone, except those in the lateral angles which are somewhat smaller. The myometrial arteries from which the coiled arteries arise are seldom smaller than the latter. In thick sections the arteries are seen to extend about three-quarters of the way through the mucous membrane, as the one shown in figure 38. In 25 μ sections, stained with Mallory's connective tissue stain, the arterial fields can be found within 0.35 mm. of the surface epithelium and single arterioles can be seen very close to it. It should be noted (fig. 5) that the reconstructed artery branches dichotomously at 'A.' Only one of the branches was reconstructed. Other branches of the coiled arteries, aside from terminal ones, are very uncommon and the few found are small like the terminal branches. Occasionally a minute type II arteriole may be found entering the mucous membrane from the myometrium. Capillaries and very thin-walled veins are especially numerous and enlarged just beneath the surface epithelium.

Menstrual phase

Early first day (no. 122); weight 4.1 kilos. This animal was given an intraperitoneal injection of 150 mg. of sodium amytal followed by an intravenous injection of 8 per cent

colloidal mercuric sulphide. When 115 cc. had been injected, the animal died. The uterus was quickly frozen and fixed in chilled 80 per cent alcohol.

MENSTRUAL RECORD OF NO. 122	
Duration of flow	Length of cycle
1	45 (Nov.-Dec.)
1	26 (Dec.)
1	25 (Jan.)
2	24 (Feb.)
2	26 (Mar.)
3	23 (Mar.-Apr.)
Killed first day (Apr. 14)	

The right ovary contains a corpus luteum in a state of early atresia. A laparotomy had been performed 7 days previously (sixteenth day of cycle) and at that time a bloody stigma was visible on this ovary, suggesting recent ovulation. The endometrium varies in thickness from 2.1 mm., where involution or desquamation had occurred, to 4.1 mm. down to 0.9 mm. at the lateral angles. At the time of killing there was no blood in the vagina but sections of the uterus show a slight extravasation into the lumen and the histological picture of the superficial zone of the endometrium clearly shows that menstruation had begun (compare fig. 25). In thick unstained sections the most striking feature as compared with the previously described specimens is the presence of large coiled arteries just beneath the denuded surface of the endometrium (compare fig. 6). Their lumina are larger in the superficial half of the endometrium than basally. The myometrial vessels, of which they are continuations, are exceedingly small. They are in fact usually abruptly constricted near their origin from the arcuate arteries in the stratum vasculare and then proceed through the inner half of the myometrium as thread-like vessels. Usually they enlarge rather abruptly as they enter the mucous membrane (7 to 9 μ to 35 to 40 μ in diameter; compare fig. 6). In 15 μ sections the arterial fields are large and particularly abundant in the superficial half of the mucous membrane where vessels 35 μ

in diameter are only separated from the uterine lumen by one or two stromal cells. The epithelium is missing over considerable areas but a sufficient amount of it remains to indicate that there has been little loss of tissue. Although the arteries come close to the lumen it is difficult to find them opening to the surface. This is also true of the capillaries and veins. When their terminal ends are found they are more or less collapsed and their walls are exceedingly thin. There is very little sulphide either in the superficial vessels or in the uterine lumen. This is to be correlated with the protracted blanching of the mucous membrane before the onset of bleeding which Markee ('33) has described. The coiled arteries do not end in terminal branches and capillaries but their walls become disorganized and collapsed as they reach the lumen of the uterus. Type II arteries are found entering the mucous membrane and ending in the basal zone. There are large cavernous venous spaces in the basal half of the mucous membrane.

First day (no. 127); weight 4.89 kilos. This animal was killed within 15 hours of the first show of blood externally. Three intraperitoneal injections of 100, 50 and 20 mg. of sodium amytal at 20-minute intervals failed to bring about complete anesthesia so a little ether was administered. The

MENSTRUAL RECORD OF NO. 127

Duration of flow	Length of cycle
2	26 (Oct.)
1	26 (Nov.)
2	53 (Dec.-Jan.)
2	48 (Feb.-Mar.)
3	25 (Mar.-Apr.)
Killed first day (Apr. 10)	

abdomen was incised but kept closed with hemostats while 40 cc. of 2 per cent colloidal mercuric sulphide were injected. The uterus was frozen and fixed in the usual fashion.

In the right ovary there is a corpus luteum which probably belongs to the last cycle. The endometrium, measured in stained sections, varies from 2.7 to 4.0 mm. down to 1.5 mm.

at the lateral angles. In thick unstained sections the coiled arteries of the endometrium are seen to be very tortuous, particularly in the upper half of the endometrium. They extend to the very surface. The zone of the myometrium adjacent to the mucous membrane appears rather anemic. The radial arteries in this zone are slightly smaller than the coiled arteries which arise from them, but the difference is not as marked as it is in the preceding specimen. Thin sections show that the surface epithelium had disappeared (fig. 26). The arterial fields are prominent. The vessels vary considerably in size, the lumen reaching a maximum of $45\ \mu$ in some arteries and only $25\ \mu$ in others. At the surface the lumina are only 7 to $10\ \mu$ in diameter. Even in $7\ \mu$ sections it is difficult to demonstrate the arteries opening to the uterine lumen. The walls of the arterioles are disorganized and the lumina disappear so that they resemble cords of cells rather than tubes as they coil about in the superficial zone of disorganized stroma. This disorganization involves only the very superficial ends of the arteries. Sometimes traces of sulphide can be recognized in these disorganized vessels showing that they were still patent to some extent although the endothelium is often indistinguishable and the blood flow was probably very meager. There is very little sulphide in the lumen of the uterus and even this is usually continuous with open veins and capillary sinuses rather than with terminal arteries. The arteries are very similar to that shown in figure 6, except that there are some terminal arterial branches in the superficial zone. Type II endometrial arteries are present.

Third day (no. 7); weight about 5 kilos. This animal was killed in February. Her menstrual record while in our colony, consists of periods of 288, 61, 24 and 35 days. On the second day of profuse bleeding following this last cycle, she was anesthetized with ether and an unsuccessful attempt was made to introduce mercuric sulphide intravenously. The uterus was frozen and prepared as usual.

There is a corpus luteum in the left ovary which belonged to the preceding cycle. The thickness of the endometrium as measured on the slides varies from 0.7 to 2.3 mm. In the photomicrograph shown in figure 27 it is obvious that there has been considerable tissue loss for there are fragments of endometrial tissue with arterial fields still intact, within the uterine lumen. The arterial fields are large, indicating that the coiled arteries are very tortuous. They vary considerably in size; some have a lumen of 35μ in diameter, in the basal zone of the mucous membrane, while others are not over 20μ . They all have very thick muscular walls. Often they are branched near the surface but these cannot be traced into capillaries. In 12μ sections it is difficult and often impossible to demonstrate the opening of these arteries to the uterine lumen. Usually as the arteries are traced superficially they are found to be contracted in disorganized stroma so that their lumina are completely occluded. They then appear as dense convoluted cords. Unlike other menstrual specimens the arterial walls do not seem to be disorganized. The radial arteries in the myometrium that are continuous with the coiled arteries are not noticeably smaller than they. There is some blood in the lumen of the uterus. This is continuous, in general, with cavernous spaces in the disorganized stroma which in turn are in communication with very thin-walled veins or large capillaries.

Second day (no. 121); weight 3.2 kilos. This adolescent animal was anesthetized, injected and the uterus subsequently treated according to the routine procedure.

MENSTRUAL RECORD OF NO. 121

Duration of flow	Length of cycle
3	56 (Apr.-June)
2	90 (June-Sept.)
3	84 (Sept.-Dec.)
Killed second day (Dec. 7)	

The right ovary contains a corpus luteum which belongs to the preceding cycle. The endometrium varies in thickness

from 2.8 to 2.0 mm. down to 1.4 mm. at the lateral angles (compare fig. 28). In thick sections the coiled arteries can be seen to extend from the myometrium to the denuded surface. They are 15 to 20 μ in diameter in the basal zone of the endometrium and are similar in form to those in figures 6 and 12. In 12 μ sections the surface epithelium is seen to be absent except in a few isolated places in the lateral angles and the arterial fields are very prominent even at the denuded surface. They contain little sulphide. As they proceed through the zone of necrotic tissue their walls become disorganized and the lumina become exceedingly small so that it is difficult to demonstrate their communication with the lumen of the uterus. The arteries have resisted the desquamation more than the surrounding stroma so that arterial fields together with small amounts of stroma are found extending in a papillary fashion beyond the general surface level (compare fig. 27). There are many large intra-stromal blood lakes in the disorganized zone of the mucous membrane. These are continuous, more basally, with veins or large dilated capillaries rather than with the coiled arteries. The radial arteries in the adjacent zone of the myometrium are always smaller than they are in the mucous membrane (compare p. 391).

Third day (no. 15); weight 4.1 kilos. This animal was injected intravenously with 125 cc. of 8 per cent colloidal

MENSTRUAL RECORD OF NO. 15

Duration of flow	Length of cycle
5	24 (Apr.-May)
6	31 (May-June)
3	32 (June-July)
5	30 (July-Aug.)
3	27 (Aug.-Sept.)
4	30 (Sept.-Oct.)
3	26 (Oct.)
3	27 (Nov.)
4	28 (Dec.)
3	25 (Jan.)
Killed third day (Jan. 28)	

mercuric sulphide containing 0.04 per cent heparin. The uterus was frozen and prepared according to the usual procedure.

The left ovary contains a corpus luteum belonging to the cycle just completed. The endometrium varies from 2.2 to 1.2 mm. in thickness and is disintegrated superficially (fig. 29). In thin sections the arterial fields are not found at the surface whereas single arterioles may be found there. These are terminal branches of the coiled arteries and are extremely small. It is difficult to prove that these small arterioles are open to the lumen of the uterus. Their lumina become almost completely occluded and the walls become disorganized so that they can hardly be distinguished from the surrounding dense stroma. Sulphide is present in the veins and these are often found open to the lumen of the uterus. The radial arteries in the myometrium are not constricted as in some of the other menstrual specimens.

Third day (no. 20). This adult animal was killed in March. The cycle just preceding this menstrual flow was 25 days in length. She was injected intravenously with 4 per cent colloidal mercuric sulphide. The uterus was rapidly frozen and prepared as usual with chilled alcohol and formalin.

The right ovary contains a corpus luteum of menstruation. The endometrium varies from 2.4 to 3.3 mm. in thickness down to 1.0 mm. at the lateral angles. The glands are dilated basally and their epithelium is laden with glycogen and appears active (figs. 12 and 30). This is not the case in other specimens from the end of the menstrual flow. In thick unstained sections the coiled arteries are seen to extend from the myometrium to the lumen of the uterus. They are unusually highly convoluted in the superficial half of the mucous membrane (fig. 12). The lumina of many of them are 35μ in diameter which is as large as the majority of the arteries of specimens from other stages of the cycle. If the convolutions of the artery are followed in figure 12 it will be seen that the arterial mass in the superficial third of the mucous membrane consists of two dichotomous branches of the single

coiled artery. The radial arteries in the adjacent myometrium are not constricted as in some menstrual specimens. In thin sections the surface epithelium is found to be intact over practically all parts of the uterus. It is probable that it had already regenerated but there could hardly have been any considerable loss of tissue. The 'necks' of the glands (O'Leary, '29) and the narrow stratum compactum in figure 30 may be taken as evidence for the latter statement. It should be noted that although there was a profuse flow of blood from the vagina for 2 days there was no fresh blood in the vagina when the animal was killed. From the appearance of the endometrium it seems unlikely that the entire surface was denuded during the period of active menstruation. Some of the coiled arteries terminate near the surface in small precapillary branches, but the majority terminate without branches as in the artery that was reconstructed (fig. 12). In such cases, as the arteries proceed through the stratum compactum, their walls become disorganized, the lumina disappear and they seem to fade into the surrounding stroma. As they are followed toward the surface, in Mallory connective tissue preparations, the dense fibrous walls become very loose in structure and the lumen usually narrows until it is completely obliterated. This disorganization of the arterial walls may be seen in figure 40. There is almost no blood in the lumen of the uterus. Very small masses of the sulphide are found scattered over the surface in denuded areas. These masses are usually in the region of the ends of coiled arteries but it is generally difficult to establish the connection of the sulphide masses with arteries because of the difficulty in following the latter. Type II arteries are found basally. Extravasations in the stratum compactum are almost entirely absent. Capillaries can be found throughout the entire mucous membrane, except in the dense stratum compactum.

Fourth day (no. 12); weight 3.0 kilos. This adolescent animal was killed in January while still menstruating. She had been under observation for 2 years. Her menstrual

record consists of a cycle of 80 days followed by one of 39 days which preceded the final menses. She was anesthetized with sodium amytal and the uterus was then injected post-vitally with mercuric sulphide-gelatine at a pressure of 130 cm. of water. The gelatine was solidified with cold water and an attempt made to inject the lymphatics with Prussian blue. The entire genital tract was fixed in 10 per cent neutral formalin.

One ovary contained a corpus luteum measuring $4 \times 2 \times$ circa 3 mm. belonging to the preceding cycle. The maximum thickness of the endometrium is 1.2 to 2.0 mm. in blocks preserved in glycerine-alcohol. In some regions the gland cells are dividing which indicates that repair had begun. The epithelium is absent except over occasional small areas (fig. 31). There is practically none of the injection mass in the endometrial arteries. The arterial fields are rather large, showing that the arteries are highly coiled. The lumina, however, are very small, never being over 15μ in diameter. The arteries as a whole are of the type shown in figure 10 in that they are very tortuous in the deeper portions of the endometrium, but they extend to the surface much as those in figure 11. At their terminations in the necrotic zone the walls are disorganized and the lumina obliterated. They are not open to the lumen of the uterus but seem to fade out into the disorganized stroma. The radial arteries in the myometrium are very small; 7μ and less in diameter.

UTERI ASSOCIATED WITH APPARENTLY INACTIVE OVARIES

Nineteenth day (no. 13); weight 3.86 kilos. This animal was given an intraperitoneal injection of 200 mg. of sodium amytal after an intravenous injection of 115 cc. of 8 per cent colloidal mercuric sulphide. The animal died of respiratory failure, probably because of an overdose of amytal. The abdomen was quickly opened and the uterus frozen and treated according to the routine procedure.

Each ovary contains an old corpus luteum. The largest follicle present in either is about 3.0 mm. in diameter. The

endometrium is 1.6 mm. in thickness. The most striking feature of this specimen is the enormous dilatation of the veins both in the myometrium and in the mucous membrane. In the basal fourth of the mucous membrane great cavernous veins are abundant (compare fig. 22). They extend to the surface epithelium but in the superficial fourth of the mucous

MENSTRUAL RECORD OF NO. 13	
Duration of flow	Length of cycle
4	32 (Apr.)
6	23 (May)
6	32 (June)
4	34 (July)
6	38 (Aug.)
4	26 (Sept.)
3	27 (Oct.)
4	28 (Nov.)
2	32 (Dec.)
5	30 (Jan.)
4	27 (Feb.)
3	Killed nineteenth day (Mar. 12)

membrane their walls become so thin that it is difficult to distinguish between veins and greatly dilated capillaries. These conditions may be agonal. Arterial fields are abundant in the basal fourth of the mucous membrane. The lumina of these arteries are relatively small (15 to 20 μ). There are no arterioles of any size above the middle of the endometrium. A reconstruction of a typical artery is shown in figure 7.

Twenty-sixth day (no. 17); weight about 5 kilos. The anesthetic used was sodium amytal with a little chloroform administered later to hasten relaxation. A gelatine injection

MENSTRUAL RECORD OF NO. 17	
Duration of flow	Length of cycle
5	24 (May)
5	31 (May-June)
4	30 (June-July)
5	29 (July-Aug.)
2	21 (Aug.)
4	Killed twenty-sixth day (Sept. 30)

was made through the aorta with hydrostatic pressure. The uterus was fixed in 10 per cent neutral formalin.

Neither ovary contains a young corpus luteum but the left contains a cystic follicle 9.5 mm. in its greatest diameter. Neither cumulus nor ovum were observed in the gross specimen. While the entire follicle has not been sectioned, the appearance of the follicular wall, particularly the disorganized, thin membrana granulosa, show it to be a cystic follicle.

The endometrium is 2.8 to 3.0 mm. in thickness, exclusive of the lateral angles (compare fig. 24). The endometrium is much thicker and the glands appear more active than in the other anovulatory specimens (compare fig. 24 with 21 to 23), a condition found associated with cystic follicles by van Herwerden ('05) and others. Obviously, this endometrium falls considerably short of the development shown by the pseudopregnant specimens from the same period of the cycle (compare figs. 17, 18, 19 and 20). The vascular injection of the endometrium is very poor, as it is in the other specimens injected post-vitally with gelatine masses. The arteries in the mucous membrane are very small in diameter. This is due to the procedure used in injecting and fixing the material and should not be considered as their normal state. The arteries are relatively very simply coiled and extend well toward the surface epithelium (figs. 9 and 24). Branches other than the terminal ones are scarce. Type II arteries can readily be found. Capillaries and veins are found uniformly distributed throughout all zones of the endometrium.

Anovulatory menstruation

First day (no. 135); weight 3.75 kilos. The routine procedure was followed in the preparation of this specimen except that a 2 per cent colloidal solution of mercuric sulphide was used.

There are two old corpora lutea in the right ovary and one in the left. The endometrium is 1.8 to 1.0 mm. in thickness (fig. 35). The coiled arteries are very tortuous and extend from the myometrium through four-fifths of the mucous

membrane (fig. 10). Their terminal branches are very small and disorganized, becoming lost in the necrotic stroma. The lumina of the coiled arteries are all about 30μ in diameter basally. The radial, myometrial arteries supplying them are about the same size. In 12μ sections the surface epithelium is found intact in some areas particularly in the lateral angles.

MENSTRUAL RECORD OF NO. 135

Duration of flow	Length of cycle
1	57 (Nov.-Dec.)
3	26 (Dec.-Jan.)
2	27 (Jan.-Feb.)
4	26 (Feb.-Mar.)
2	42 (Mar.-Apr.)
Killed first day (Apr. 23)	

The lumen of the uterus is distended with blood. Mercuric sulphide may be detected throughout this entire mass. The sulphide is continuous with the sulphide darkened blood in superficial, ruptured hematmata which in turn are connected basally with very thin-walled veins or greatly dilated capillaries. The veins of the myometrium are so large and irregular in form that they give a spongy appearance to the entire myometrium.

Second day (no. 125); weight 3.07 kilos. This adolescent animal was injected and the uterus prepared in the usual

MENSTRUAL RECORD OF NO. 125

Duration of flow	Length of cycle
2	23 (Aug.-Sept.)
1	183 (Sept.-Mar.)
4	21 (Mar.)
4	26 (Apr.)
Killed second day (Apr. 30)	

manner except that a 2 per cent solution of mercuric sulphide was used.

Neither ovary contains a corpus luteum. The endometrium is about 2.0 mm. in thickness (fig. 33). The coiled arteries as seen in thick sections extend through the deeper three-quarters of the mucous membrane. The superficial quarter

appears to be rather anemic as there is little sulphide in the vessels. A reconstruction of an artery is shown in figure 13. Its small terminal branches do not reach the surface. In the basal third of the endometrium there is a plexus of large cavernous veins. The radial myometrial arteries are considerably smaller in the inner third of the myometrium than the coiled arteries in the mucous membrane. In thin stained sections the epithelium is intact in some places. There is very little blood in the lumen of the uterus and when veins and capillaries are found opening there they are almost always collapsed. Type II endometrial arteries are present.

Second day (no. 113); weight 4.44 kilos. This animal was given an intravenous injection of 25 cc. of 8 per cent colloidal mercuric sulphide. She collapsed from respiratory failure as an intravenous injection of sodium amytal was begun.

MENSTRUAL RECORD OF NO. 113

Duration of flow	Length of cycle
1	24 (Nov.)
2	27 (Dec.)
2	32 (Jan.)
2	31 (Feb.)
2	87 (Mar.-May)
2	34 (June)
2	27 (July)
2	39 (Aug.)
2	50 (Sept.-Oct.)
2	30 (Nov.)
2	28 (Dec.)
Killed second day (Dec. 22)	

After 50 minutes she had recovered and 50 cc. more of the sulphide were injected. Ether was administered and the uterus frozen and prepared as usual with chilled alcohol and 10 per cent neutral formalin.

The right ovary contains an old corpus luteum which does not belong to the preceding cycle; in the left, there are two very old ones. The endometrium varies in thickness from 2.0 mm. in the midline to 1.5 mm. in the lateral angles (fig. 34). In thick unstained sections the coiled arteries in the endometrium are almost indistinguishable. This is not due to

their absence or scarcity but rather to their small size, the lumina seldom being over 15μ in diameter. They are relatively simple in form (fig. 11). The arterial fields seem to be crowded in between the dilated glands and extend to the denuded surface where some of the arteries are open to the uterine lumen. The arterial walls in the superficial zone are disintegrated and their lumina partially occluded. The termination of one of the reconstructed arteries is indicated by the 'arrow' in figure 41; where the arterial wall is entirely disorganized and the vessel seems to fade out into the surrounding stroma. The black mass at the end of the artery is mercuric sulphide that had accumulated during the intravenous injection (60 to 70 minutes). Since this mass is entirely surrounded with stromal cells it is evident that the circulation through the artery was feeble. Four successive coils of the vessel appear below the arrow (fig. 41) and show the progressive disintegration of artery. The sulphide in the lumen of the uterus is continuous with that in veins as well as with some arteries. Since no branches were found arising from the coiled arteries the venous blood must have its origin from type II endometrial arteries and capillaries in the basal zone, or by regurgitation from veins which directly drained the myometrium.

The radial arteries in the inner quarter of the myometrium taper off toward the mucous membrane (fig. 39). This cone-shaped form is not due to branching of the artery but to an actual progressive constriction. As they enter the mucous membrane and become the coiled endometrial arteries their lumina are 10 to 15μ in diameter. The two reconstructed arteries (fig. 11) were supplied by such constricted myometrial vessels.

Third day (no. 128); weight 2.0 kilos. This adolescent animal was bleeding freely from the vagina when killed. An intravenous injection of 8 per cent colloidal mercuric sulphide was given. When about 35 cc. had been injected she died from respiratory failure. The uterus was frozen with chilled acetone and fixed in Champy's fluid and formol-chrom-sublimate.

No corpora lutea were seen in 1-mm. sections of the ovaries. The endometrium varies from 1.8 to 1.0 mm. in thickness as measured on blocks of tissue in glycerine-alcohol. The lumen of the uterus is distended with blood and desquamated tissue, the latter indicating some tissue loss (compare fig. 36). The arterial fields are large in 10 μ sections but the arterial lumina seldom exceed 20 μ in diameter. They are very similar in general form to those in specimen 125 (compare fig. 13), with the exception that most of them terminate by opening to the surface rather than by breaking up into precapillary arterioles. In this respect they resemble the arteries of no. 113 (fig. 11), however, the openings are more distinct. Peripherally the walls are disorganized and the vessels are usually

MENSTRUAL RECORD OF NO. 128

Duration of flow	Length of cycle
2	18 (Aug.)
1	105 (Sept.-Dec.)
3	28 (Dec.-Jan.)
3	76 (Jan.-Mar.)
Killed third day (Apr. 5)	

distended with erythrocytes. There is almost no sulphide in these arteries near their terminations which indicates that little blood entered them during the period of injection. This is an additional indication that our method has preserved the status quo at the time of killing. The radial arteries in the myometrium are always much smaller than the coiled arteries. The lumina of the former range in size from 4 to 10 μ in diameter, and in many cases practically no lumen can be detected. Often the change in the size of the lumen is very abrupt as the artery passes from myometrium into the mucous membrane (compare fig. 6). Veins can be found opening directly to the lumen of the uterus. They are usually collapsed; however, they contain more sulphide than the terminal arteries. Type II arteries are present in the basal zone of the mucous membrane.

UTERI OF DOUBTFUL CLASSIFICATION

Thirteenth day (no. 133); weight 5.11 kilos. This animal was received October 17, 1931. On November 17th a dead, 10- to 12-cm. fetus was aborted. A 6-day period of menstruation began on January 11th. After a cycle of 37 days there was a menstrual flow of 3 days' duration. This second cycle proved to be 51 days in length and was followed by a flow of 2 days' duration. She was killed April 20th, on the thirteenth day of the cycle. The routine procedure was followed in the preparation of this specimen.

There are no corpora lutea or follicles over 1.2 mm. in diameter in either ovary. From her menstrual record since the abortion it would seem very probable that this may be the thirteenth day of a long cycle. Therefore, the fact that there is no large follicle present at this time does not necessarily indicate that this would have been an anovulatory cycle. The junction of myometrium and the mucous membrane is very indefinite (fig. 21) but the endometrium is about 1.5 mm. in thickness. There are no typical arterial fields in the endometrium. The only arteries present are in a very narrow basal zone. They have thick walls, very small lumina and are not greatly coiled. The walls of many of the arteries in the myometrium are hyalinized, especially those in the inner third. Hyalinized arteries are generally recognized as indicating previous placental sites. It will be remembered that the two placentae in the macaque cover much of the dorsal and ventral uterine walls. Although arteries are almost entirely lacking in the endometrium, veins and capillaries are abundant and contain sulphide. The superficial third of the endometrium appears to be slightly edematous.

Twenty-first day (no. 114); weight 5.0 kilos. This animal was anesthetized with an intravenous injection of sodium amytal which was followed by an injection of 120 cc. of colloidal mercuric sulphide containing 0.4 per cent heparin. The uterus was prepared in the usual manner.

This is a 'problem' specimen. In the section shown in figure 23 the appearance of the glands, stroma, and endometrium as a whole give no hint of pseudopregnancy although

this is a twenty-first day specimen. In the right ovary there are two corpora lutea, one of them measuring 6.3×5.2 mm.; it is, however, atypical (Corner). A reconstruction of a typical artery of the endometrium is shown in figure 8. The terminal end of this artery is about 7μ in diameter and is scarcely distinguishable from a capillary. Arterioles are not present in the superficial third of the endometrium. Branches from the coiled arteries are rare and the vessels progressively decrease in size, apparently without giving off branches. In

MENSTRUAL RECORD OF NO. 114

Duration of flow	Length of cycle
2	95 (July-Oct.)
2	23 (Oct.-Nov.)
3	25 (Nov.-Dec.)
2	21 (Dec.)
3	23 (Jan.)
3	Killed twenty-first day (Feb. 13)

the basal zone their lumina are 20 to 25μ in diameter, which is somewhat smaller than those in the pseudopregnant specimens. Small veins and capillaries are abundant throughout the entire mucous membrane and are well filled with the sulphide indicating that there was a good circulation. Large cavernous veins are occasionally found in the basal zone.

DISCUSSION

THE ARTERIAL PATTERN OF THE ENDOMETRIUM

We have been unable to find an adequate description of the vascular pattern of the endometrium in any mammal. The few descriptions of the uterine vascular system in *Homo* are superficial and in general maintain that the vascular pattern is subordinate to the arrangement of the glands. This relationship appears to be true between the glands and the capillaries but certainly the arteries and perhaps the veins too, have a distinctive pattern.

In *Macacus rhesus* the endometrium is supplied by two distinct types of arteries. Type I, the 'coiled' artery, has a

characteristic pattern and undergoes cyclic changes. During most of the cycle it seems to furnish the bulk of the blood supply to the endometrium. It enters the mucous membrane as a continuation of a rather straight radial artery in the myometrium which in turn springs directly from the stratum vasculare. In the endometrium it proceeds in a tightly coiled, tortuous course toward the surface epithelium; the entire spiral ranging from 0.2 to 0.5 mm. in diameter. Figures 37 and 38 show such arteries in cleared thick sections. In thin sections they appear as limited areas filled with numerous transverse and oblique sections of the artery often surrounded by a dense stroma. Such 'arterial fields' are very prominent in figures 17, 18 and 32. From a study of the injected material and projection reconstructions from thin sections it is evident that the arterial columns seen in thick sections, and the arterial fields, in thin sections, are due to the extreme tortuosity of single arteries and not to a group or tuft of arteries (compare figs. 1 to 13). Their extent through the mucous membrane toward the surface epithelium varies throughout the menstrual cycle. They give rise to very few branches; many that were carefully studied had none (compare fig. 3). A few have been found to branch dichotomously in the basal or middle thirds of the mucous membrane (compare figs. 5 and 12). Peripherally they divide rather abruptly into numerous small terminal arterioles. Thus the bulk of the blood to the endometrium is carried well toward the surface epithelium before passing into capillaries. This seems to be a structural arrangement suited to the development of edema in the superficial portion of the endometrium under certain conditions. The physiological activity of the coiled arteries is probably the primary factor in the production of the blush and blanch phenomenon of the mucous membrane described by Markee ('29). The only data concerning the exact form of these arteries in other species is the reconstruction of an artery in *Homo* by Bartelmez ('31) which is similar to those described here except for its numerous subterminal branches. The cyclic variations of the coiled arteries will be discussed later.

Type II arteries are very small and never extend beyond the basal zone which thus is given an independent blood supply. These vessels seldom have a luminal diameter of over 10μ . An artery of this type is shown in figure 42 where it may be compared directly with a typical, large, coiled artery. They are distinct types; arteries of an intermediate size were not found. The significance of the type II arteries during menstruation is considered on page 393.

From the observation of Saito and Bartelmez it would seem that conditions in Homo are somewhat different as the basal zone there appears to be supplied by a capillary anastomosis with vessels in the myometrium and basal branches from the large coiled arteries.

CYCLIC CHANGES IN THE ARTERIAL PATTERN

Evidence of preservation of functional form of vessels

Before discussing the cyclic changes in the arteries it will be well to consider the evidence for the extent to which the technique employed in the fixation of the material has preserved their form at the time of freezing. The technique is outlined on page 354. A few specimens were fixed in the more conventional manner of removing the fresh tissue directly to fixing fluids at room temperature (nos. 3, 7 and 12) and invariably the arteries are much smaller than in specimens fixed by the chilled alcohol procedure. Localized regions of marked contraction of certain myometrial arteries, to be discussed later, have only been observed in the menstrual phase of the cycle (compare p. 391) which suggests that the functional form of the arteries at the time of fixation was preserved. The size of the lumina varies in what are otherwise comparable arteries of a given specimen which would not be expected had the arteries undergone agonal contraction. It may be added that contraction waves have been fixed by this method as they passed down the horns of the rat uterus (unpublished work of I. Rossman, The University of Chicago). Although we have no data as to the extent to which the arteries have been altered by the procedure it can be said

that in our material the conditions in vivo have suffered less alteration than in any other histologic preparations of the vascular system that have been described. Attention may be called to the specimens 122 and 113 (pp. 367 and 379) in which the condition of the blood vessels during menstruation agrees with the description of similar stages observed in vivo, without an anesthetic, by Markee. The phases of the blush and blanch phenomenon have not usually been revealed in our uteri probably because the use of anesthetics causes a marked reduction in the circulation of the uterine mucous membrane, especially superficially.

Ovulatory cycles

The large, coiled arteries are directly involved in the progravid and menstrual changes of the mucous membrane. They appear to respond to the same stimuli concerned in the hyperplasia and hypertrophy of the glands and stroma. Their response, however, as far as this study indicates, is limited to growth and to differentiation from the capillary bed. If the superficial extent of the coiled arteries is noted in the series of specimens with corresponding ovarian activity (pp. 357 to 367 and figs. 1 to 5) it is apparent that they exhibit a progressive growth or differentiation through the endometrium toward the uterine lumen during the menstrual cycle. In the first half of the cycle the endometrium increases in thickness faster than the arteries differentiate, hence the superficial portion is only supplied by capillaries and veins. In the progravid phase of the cycle, however, the arteries continue to differentiate while the mucous membrane thickens only slightly. Thus, while in the proliferative phase the arteries only extend, roughly, through the basal half of the endometrium, in the late progravid (pseudopregnant) phase 'arterial fields' and terminal arterial branches are found immediately under the surface epithelium (compare figs. 5 and 43). This agrees with the condition of the artery reconstructed, from the human pseudopregnant uterus, by Bartelmez ('31). It would not be amiss to refer here to one

of the early first day specimens where, in spite of the lack of any appreciable amount of desquamation, the spiral arteries are very tortuous right at the surface (fig. 6). This arterial growth is not only manifest in that the vessel has differentiated to the surface but also in its extreme tortuosity. The former is by differentiation from capillaries while the latter is due to hyperplasia and hypertrophy of the arterial walls. Since subterminal branches are very few in number this peripheral differentiation must involve only one of the terminal branches which gains ascendancy over the others, usually, to the extent of their complete obliteration. This accounts for the apparent migration of the site of the terminal branching during the cycle (compare figs. 3 to 6).

Anovulatory cycles

When a series of specimens from cases which show no histologic evidence of ovarian activity are arranged according to the number of days since the last period, no arterial changes comparable to those just described are to be seen (compare figs. 7 and 8 with figs. 1 to 5). Even though figures 7 and 8 are of specimens of the nineteenth and twenty-first days respectively they do not show the development seen in figure 4 (sixteenth day). This is in harmony with the differences in the general development of the endometrium in the two series (compare figs. 22 and 23 with 17). The twenty-sixth day case (figs. 9 and 24) represents an intermediate condition associated with a cystic follicle.

Since there are exceptionally long menstrual cycles and occasional amenorrheic periods 6 weeks or more in duration it might be suggested that the absence of arterial development in the anovulatory series merely indicates that menstruation is not imminent. This point is elucidated by the consideration which follows, of the form of the arteries in specimens of the menstrual phase.

INVOLVEMENT OF THE ARTERIES IN MENSTRUATION

The specimens of the menstrual phase also fall into two groups; i.e., those with corresponding corpora lutea in early stages of degeneration and those with ovaries containing no recent corpora lutea. The former have endometria with the characteristic glands of pseudopregnancy or early involution (rather complete in fourth day specimens) while the latter have endometria of the 'interval' type (compare figs. 25 to 32 with figs. 33 to 36).

Extent of arterial loss by desquamation

Menstruation following ovulatory cycles. Since terminal arterioles and in fact the coiled arteries proper, are found immediately under the surface epithelium in late pro gravid uteri, it is apparent that during menstruation any desquamation will radically affect them. A survey of the specimens menstruating after ovulatory cycles (first day, 2 specimens; second day, 2 specimens; third day, 2 specimens; and fourth day, 1 specimen) reveals, with two exceptions, a loss of all capillaries and terminal branches together with an undeterminable loss of the vessel itself. In one of the exceptions (no. 122, first day) no desquamation has as yet taken place. However, there is a destruction of the superficial capillary bed and the ends of the arteries are necrotic. It is apparent that any desquamation will involve the coiled arteries (compare fig. 6). In the other case (no. 15, third day) the coiled arteries have not been directly involved although there has been some loss of tissue. The full premenstrual extent of the coiled arteries is preserved since terminal arterial branches are present. This is a transitional case.

Menstruation following anovulatory cycles. The involvement of the coiled arteries in the menstrual desquamation in cases without previous pseudopregnant growth is very different from that in the preceding series. There are four specimens in this series. In specimens 135 (first day) and 125 (second day) and 128 (third day) the degeneration has only involved the capillaries and parts of the terminal arterioles. The presence of terminal arterial branches shows that

the full extent of the coiled arteries has been preserved. Since there has been some tissue lost this is proof that in the premenstrual phase the arteries never reached the state of development found in pseudopregnant specimens and furnishes very convincing evidence that the lack of arterial development in our premenstrual, anovulatory, specimens, is no evidence for considering such specimens examples of abnormally long cycles. The difference in the degree of involvement of the coiled arteries in ovulatory and anovulatory menstruation is apparent in the reconstructions. In figure 6 (first day following an ovulatory cycle) the arterial coils are at the very surface although there had been almost no loss of tissue (compare p. 367). In figures 10 and 13 (first and second days, respectively) of specimens menstruating after anovulatory cycles the coiled arteries are not at the surface and their terminal arterioles are still intact although some tissue has been lost. Specimen 113 (second day following an anovulatory cycle) presents an intermediate condition. Here the arteries are at the denuded surface and were bleeding during the period of injection. However, they are relatively very simple in form and probably did not develop the pro gravid form during the preceding cycle.

From these observations of the marked difference in the degree of damage to the coiled arteries in the anovulatory and ovulatory specimens it would appear that there would be a similar marked difference in the amount and nature of the menstrual flow. Such a difference, however, does not exist. Hartman ('32) in a consideration of the general features of menstruation in *Macacus rhesus* says that, "the marvel is, however, that the swollen, succulent, highly vascular pre-gravid endometrium following ovulation should deliver little if any more menstrual blood than the thin 'interval' type of endometrium." The subsequent discussion will offer some explanation to this problem and in addition it may be suggested that perhaps in the anovulatory type the menstrual blanch (Markee, '33) is shorter in duration and the consequent greater vascularity of the uterus results in a relatively greater loss of blood.

Evidence of a reduced blood flow

When the arteries are found at the surface, as they are in most specimens of menstruation following ovulatory cycles, the lumina are usually more or less completely occluded. This is accomplished either by a highly contracted state of the arterial wall as in the third day specimen (no. 7, p. 270), or, more commonly, by a disorganization or necrosis of the arterial wall. This disorganization usually appears as a loosening up of the fibrous coat and a varying degree of encroachment of this tissue on the lumen (fig. 40). Even in the most favorable histological sections of intra-vitally injected specimens no signs of a good circulation through such arteries (compare fig. 12) can be detected. In occasional specimens (nos. 113, p. 379 and 128, p. 380) where the lumina are patent there is likewise no evidence of a strong circulation. On the contrary, the small blood sulphide mass at the end of the artery in figure 41 has required 60 to 70 minutes to collect and it is completely, yet very delicately, surrounded with totally disorganized, necrotic stroma cells. Mercuric sulphide was first introduced in this case without the use of any anesthetic (compare p. 379). Surely any approach to normal arterial pressure in this artery would have disrupted this delicate necrotic stromal covering. In no case has any evidence been found that would indicate typical arterial flow or spurting from the ends of the disorganized coiled arteries. The blood and sulphide present in the uterine lumen may readily be found continuous with sulphide in open veins or more commonly with open hematomata which are supplied basally by thin-walled veins or large capillaries. It is interesting to note in this connection that Sampson ('11) found that when he injected colored masses into the arteries of extirpated menstruating uteri the injection mass did not appear in the lumen of the uterus. However, when he injected through the veins the mass did reach the uterine lumen.

From these observations it appears that the menstrual blood is primarily of venous origin. This may explain the

fact that the intensity and duration of the flow is the same in anovulatory and ovulatory cycles in spite of the marked differences in the degree of involvement of the coiled arteries. That menstrual blood is principally of venous origin is the principal contention of Keiffer ('33) and histological evidence of it has been presented by Bartelmez ('33) who has summarized histological and cytological evidence indicating a reduced arterial blood flow during menstruation in Homo.

Factors controlling the rate of blood flow through the coiled arteries

Tortuosity. Leopold (1877) suggested that the very tortuosity of the endometrial arteries would greatly retard the flow of blood through these vessels. What we know of the flow of fluids through tubes justifies this conclusion. The reconstructions of the arteries (especially figs. 4 to 6) show that they are more tortuous than has been suspected. This retardation of blood flow may cause an increase in the permeability of the capillaries with consequent edema and diapedesis of both leucocytes and erythrocytes. The absence of subterminal branches and the independent blood supply of the basal zone (compare pp. 384-385) would limit these changes to the superficial region. This may be the normal process in the production of the pabulum bed for the implantation of the ovum as mentioned by Hartman ('31). However, this factor cannot be the only, or even the principal factor in the production of the ischemia of menstruation since it does not exist in menstruation following an anovulatory cycle.

Contraction cones. In most of the menstrual specimens the radial arteries, that are continued into the endometrium as the coiled arteries, are constricted as they pass through the inner fourth of the myometrium. In thick, cleared sections of uteri intra-vitally injected with mercuric sulphide the radial arteries in this zone appear as elongated cones with their apices continuous with the coiled arteries (compare fig. 39). In one specimen (no. 122, p. 367) they were con-

tracted throughout the entire extent from the stratum vasculare to the mucous membrane. These cones are not due to a gradual diminution in size due to branching since this is unusual. There is usually a very abrupt change in the diameter of the lumen as the artery passes from myometrium into endometrium ($7\ \mu$ or less to 25 to $40\ \mu$; compare fig. 6). These constricted regions are present to a more or less marked extent in all menstruating specimens except in numbers 7, 15, 20 and 135. Specimen 7 (third day; p. 370) is peculiar in that the walls of the arteries at the denuded surface are not disorganized but simply highly contracted. In specimens 15 (third day; p. 372) and 135 (first day; p. 377 and fig. 10) the coiled arteries do not extend to the denuded surface; only the capillary net and small terminal branches are involved in the superficial necrosis. Finally it should be noted that the artery in figure 12 (no. 20; third day) is more highly coiled in the superficial zone than that in any other menstruating specimen. It also has an almost completely intact surface epithelium.

The phenomenon of the periodic blush and blanch of the endometrium as described by Markee ('29) appears to be due to the periodic contraction of these radial myometrial arteries. It is true that such constrictions have only been found in menstruating specimens but this may be due to the greater duration of the constricted phase during menstruation as observed *in vivo* by Markee ('33).

These constrictions must greatly reduce the blood flow to the coiled arteries and their terminal capillary beds and offers a mechanism for the production of the menstrual ischemia. This is additional evidence for the idea that the tissue disorganization and loss in menstruation is an anemic necrosis. This was suggested by R. Meyer ('20) and supported by Bartelmez ('33) with histologic evidence.

Bucura ('03) described 'Polster' or endothelial cushions in the uterine arteries in *Homo* and thought they might function in reducing the arterial blood flow. Joachimovitz ('28) and Bartelmez ('33) have also observed these thickenings of the intima. The former has found them abundant

in the inner zone of the myometrium next to the mucous membrane. There is, to be sure, no good evidence that they occur invariably in normal uteri nor is there histological evidence that they have a special physiological function at the time of menstruation. They might, however, have a function homologous to that of the periodically formed cone-shaped constrictions here described.

Vascular control of the extent of necrosis, desquamation, and subsequent reconstruction

After the initial desquamation of the superficial zone in menstruation, be it due to necrosis produced by a condition of ischemia or other factors, it is apparent that, in pseudo-pregnant specimens at least, there is a complete disruption of the superficial capillary bed. If the entire mucous membrane depended on this fountain-like vascular source for its capillary blood, as is indicated by the scarcity of subterminal branches, it would seem that the entire mucous membrane would be subject to an anemic necrosis. It is here that the small type II arteries of the endometrium play their most important role. Even though they are very small in proportion to the coiled arteries they nevertheless supply a capillary bed basally in the mucous membrane. It is suggested that the superficial anemic necrosis and desquamation proceeds toward the myometrium down to a level where they can compensate for the coiled arteries so as to prevent degenerative changes. In other words, the region of the mucosa which suffers no damage during menstruation represents the potential capillary bed of the type II arteries. Their number and the size of their functional lumina is perhaps the principal determiner of the amount of necrosis and consequent loss of tissue. This would account for the great variation in the amount of tissue lost in different specimens and in different regions of the same specimen.

The coiled arteries are reclaimed below the necrotic zone after menstruation. In lieu of detailed evidence, the following assumption is made as to the first step in the stage of

repair of the vascular bed. Below the necrotic zone where the blood supply offered by type II arteries is sufficient to prevent such degenerative changes, capillaries grow out from the ends of the coiled arteries and establish connections with the existing capillary bed. The subsequent history of the coiled arteries is growth and differentiation from this new capillary mesh-work.

SUMMARY

1. So far as we know this is the first systematic account of the arterial pattern of the endometrium in any mammal.

2. An effort has been made to obtain functional vascular beds by vital injections with a non-toxic colloidal mercuric sulphide solution, followed by rapid freezing and fixation in chilled alcohol.

3. These are two distinct types of arteries: I, large, tortuous, coiled arteries which are characteristic; and II, small arteries that extend only into the basal zone of the mucous membrane.

4. The coils of a type I artery are closely wound so that it forms a radial column through the mucosa.

5. 'Arterial fields' seen in thin sections are not due to a tuft of arteries but rather to a section through one of the radial columns composed of a single, tortuous artery surrounded by dense stroma.

6. The coiled arteries have very few branches along their course but divide peripherally, rather abruptly, into numerous precapillary arterioles.

7. In ovulatory cycles the coiled arteries exhibit a progressive increase in extent toward the uterine lumen and an increase in tortuosity so that in the late progravid phase they are present immediately under the surface epithelium.

8. In anovulatory cycles this marked growth and differentiation in the premenstrual period does not occur, consequently, at the time of menstruation the arterial pattern is comparable to that of the proliferative phase of the ovulatory cycle.

9. A slight degree of arterial, and general endometrial, growth is associated with cystic follicles and atypical corpora lutea.

10. During ovulatory menstruation the terminal branches, and parts of the coiled arteries proper, are usually lost while in anovulatory specimens no such marked involvement of the arteries occurs.

11. Evidence is presented to show that the flow of blood through the coiled arteries is reduced during menstruation and that much of the blood lost is from veins opening into the uterine lumen.

12. The blood flow through the coiled arteries is controlled by, a) tortuosity, and b) contraction, in the inner fourth of the myometrium, of the radial myometrial arteries that supply them. The latter have been observed only during the menstrual period.

13. Due to the fountain-like distribution of the coiled arteries (subterminal branches being scarce) these constrictions produce at the onset of menstruation an ischemic necrosis of the superficial part of the mucous membrane.

14. The type II arteries in the basal zone are not involved in the cyclic changes and in their area of distribution prevent menstrual necrosis. Variations in their size and the extent of their potential capillary bed are perhaps the principal factors in determining the amount of necrosis and consequent loss of tissue.

15. Since the coiled arteries are reclaimed below the necrotic zone after menstruation it may be suggested that below the necrotic area where the blood supply of the type II arteries is intact, capillaries sprout out from the ends of the coiled arteries and establish connections with the existing capillary bed. This is the first step in the stage of repair.

16. Reconstructions of certain representative uterine glands are submitted with the arteries. They differ somewhat in form from the human glands described by O'Leary ('29).

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PLATE 1

EXPLANATION OF FIGURES

Projection reconstructions ($\times 40$) of endometrial glands and of lumina of coiled arteries.

1 Fourth day (no. 120); early postmenstrual phase. Note the large number of branches. Compare figure 32.

2 Eighth day (no. 132); early proliferative phase. Compare figure 15.

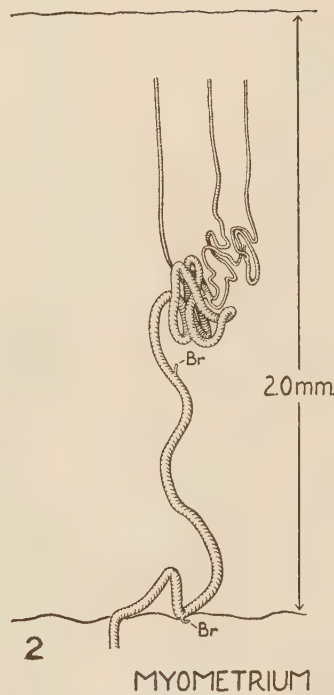
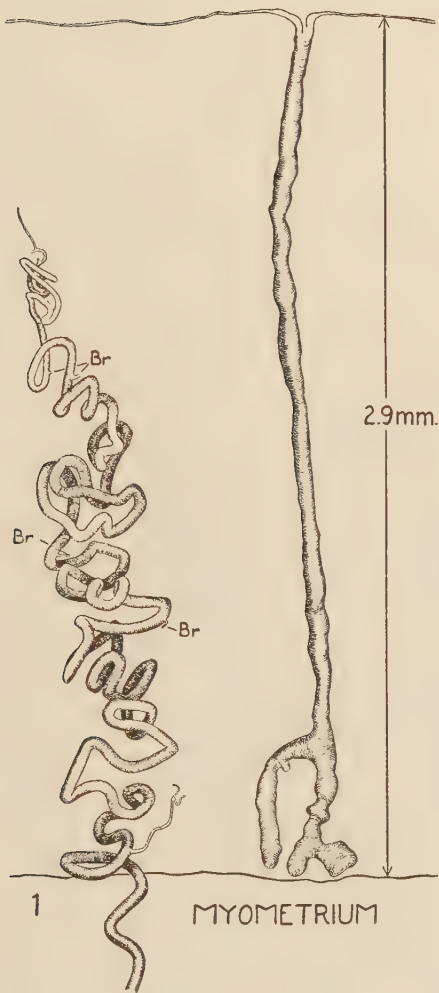


PLATE 2

EXPLANATION OF FIGURES

Projection reconstruction ($\times 40$) of endometrial glands and of lumina of coiled arteries.

3 Eleventh day (no. 111); proliferative phase; ovulatory cycle. Compare figure 16.

4 Sixteenth day (no. 116); early pro gravid phase; ovulatory cycle. Compare figure 17.

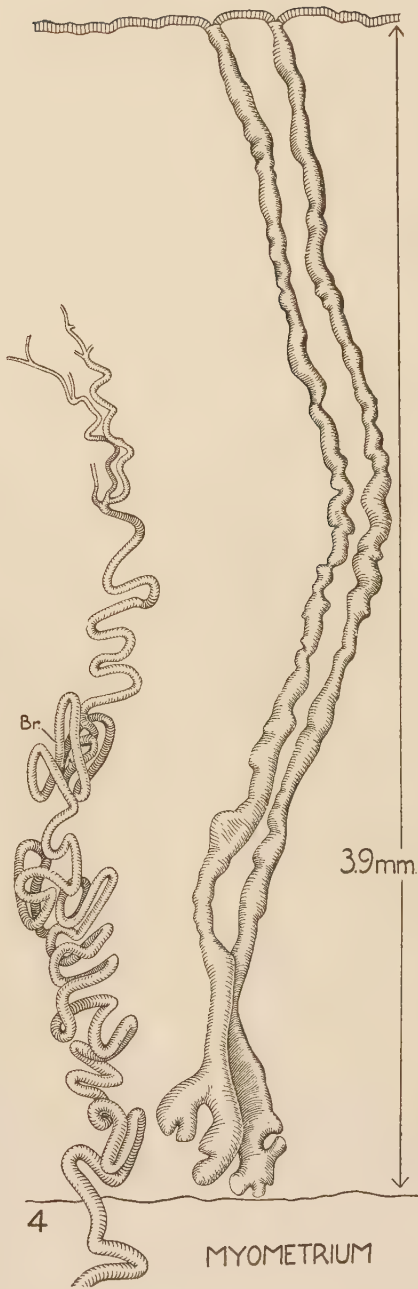
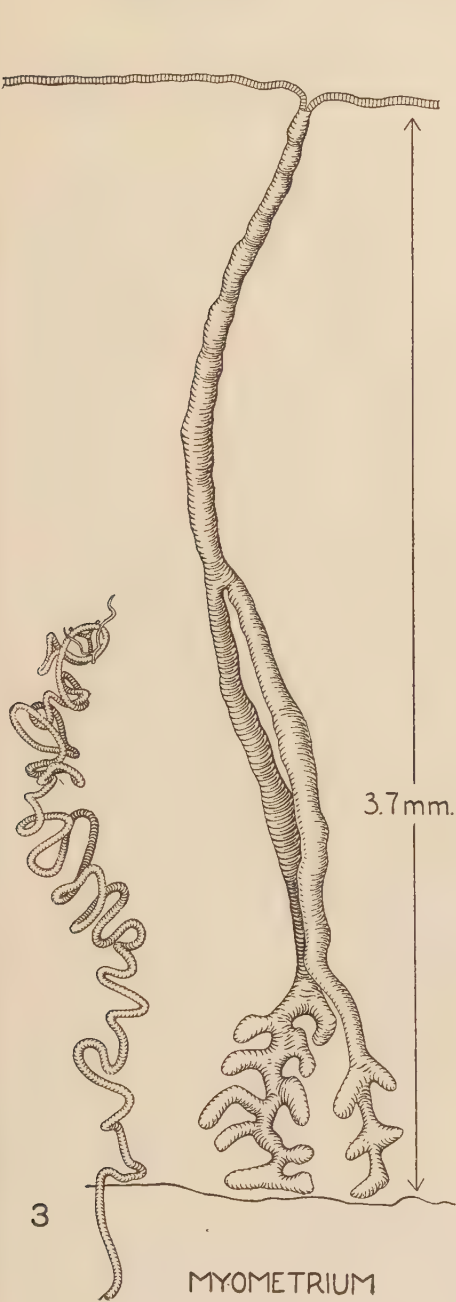


PLATE 3

EXPLANATION OF FIGURES

Projection reconstructions ($\times 40$) of an endometrial gland and of lumina of coiled arteries.

5 Thirteenth day (no. 115); late pro gravid phase; ovulatory cycle. Note the dichomotous branching at 'A.' Only one of the branches was reconstructed. Compare figure 18.

6 Early first day (no. 122); menstrual phase; ovulatory cycle. Compare figure 25.

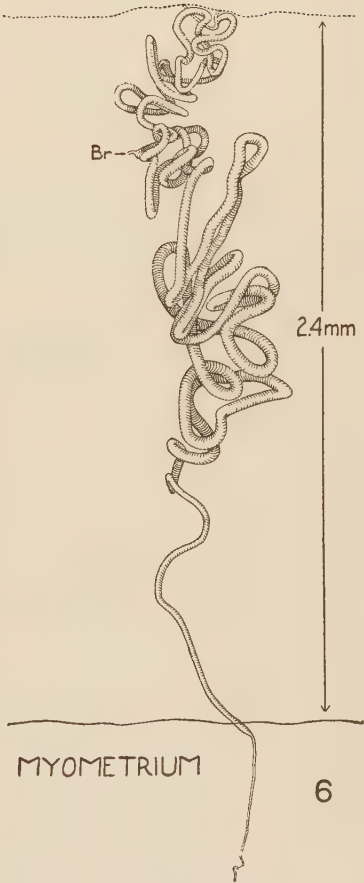
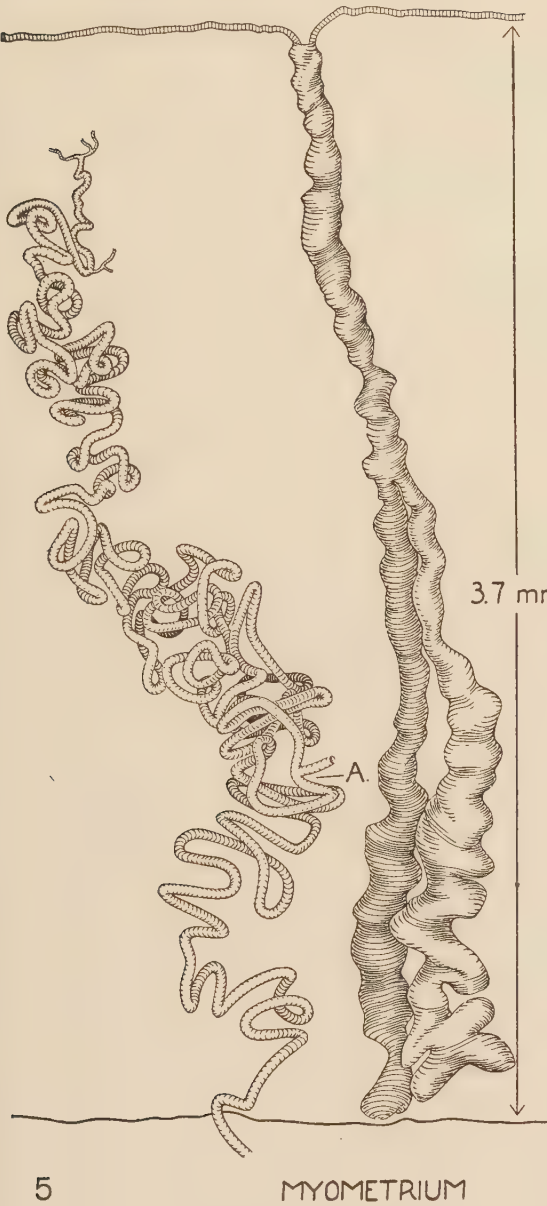


PLATE 4

EXPLANATION OF FIGURES

Projection reconstructions ($\times 40$) of lumina of coiled, endometrial arteries.

7 Nineteenth day (no. 13); anovulatory cycle. Compare figure 22.

8 Twenty-first day (no. 114); anovulatory cycle. (Compare p. 382 and figure 23.)

9 Twenty-sixth day (no. 17); anovulatory cycle. One ovary contained a large cystic follicle. Compare figure 24.

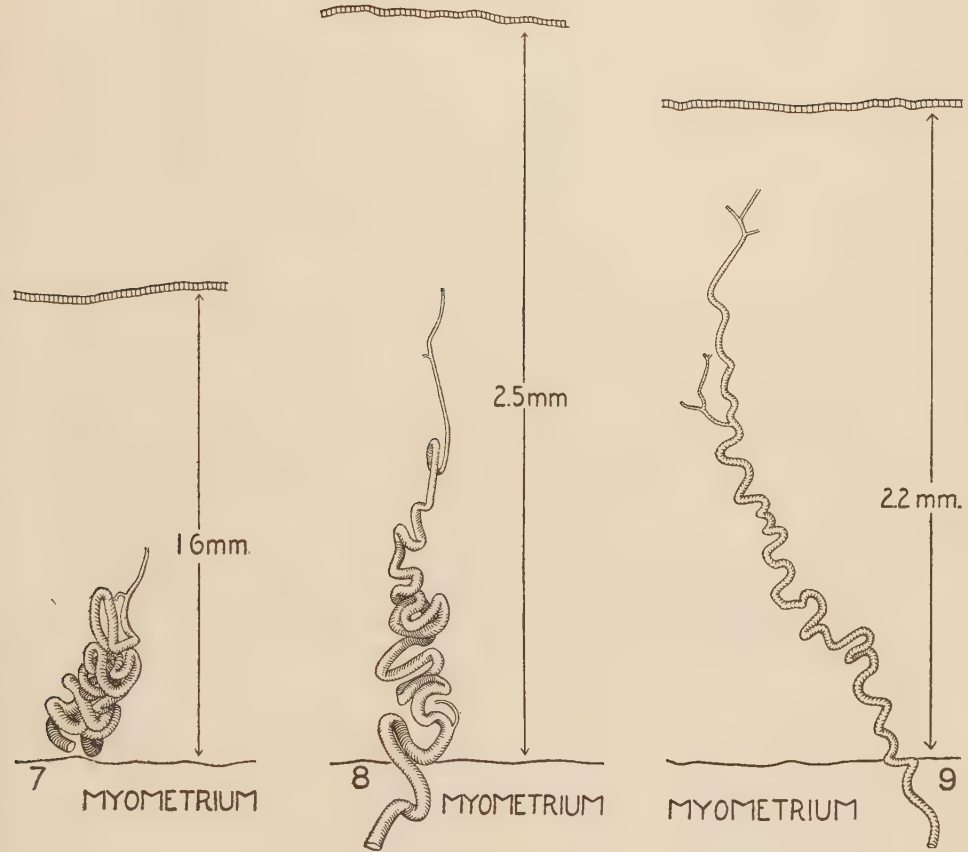


PLATE 5

EXPLANATION OF FIGURES

Projection reconstructions ($\times 40$) of endometrial glands and of lumina of coiled arteries.

10 First day (no. 135); menstrual phase; anovulatory cycle. Note the presence of terminal branches. Compare figure 35.

11 Second day (no. 113); menstrual phase; anovulatory cycle. The desquamation has involved the arteries as well as their terminal branches. A section through the end of the artery on the right is shown in figure 41. Compare figure 34.

12 Third day (no. 20); menstrual phase; ovulatory cycle. Note the dichotomous branching at 'A,' and the absence of terminal branches. The wall of the artery just beneath the surface is necrotic (compare figs. 40 and 30).

13 Second day (no. 125); menstrual phase; anovulatory cycle. The artery has not been involved in the superficial necrosis. Compare figure 33.

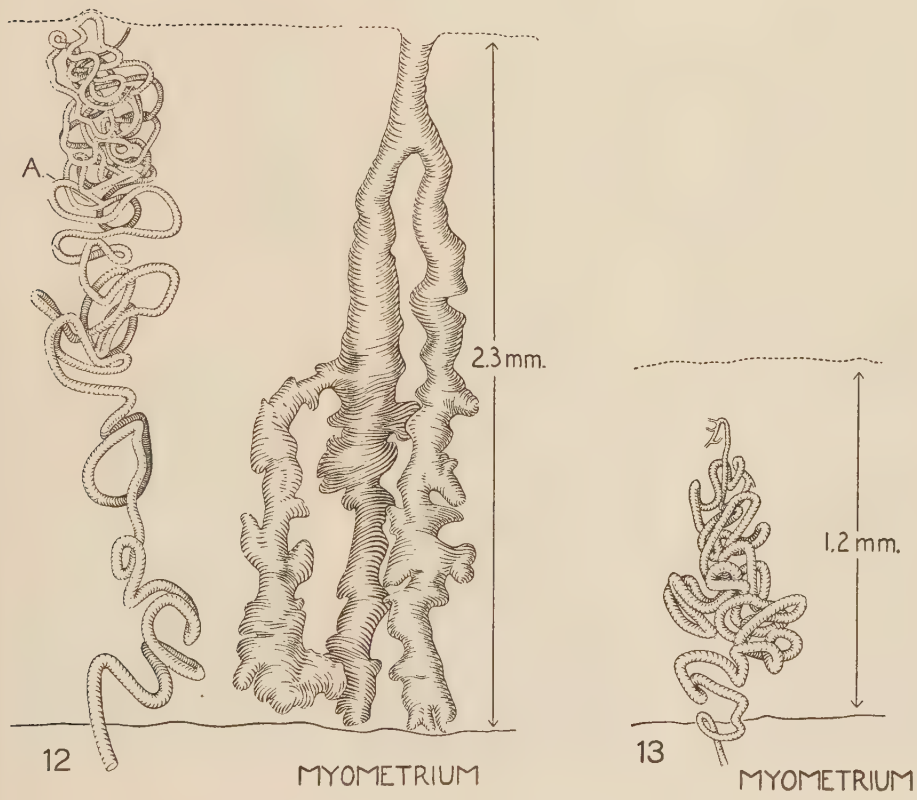
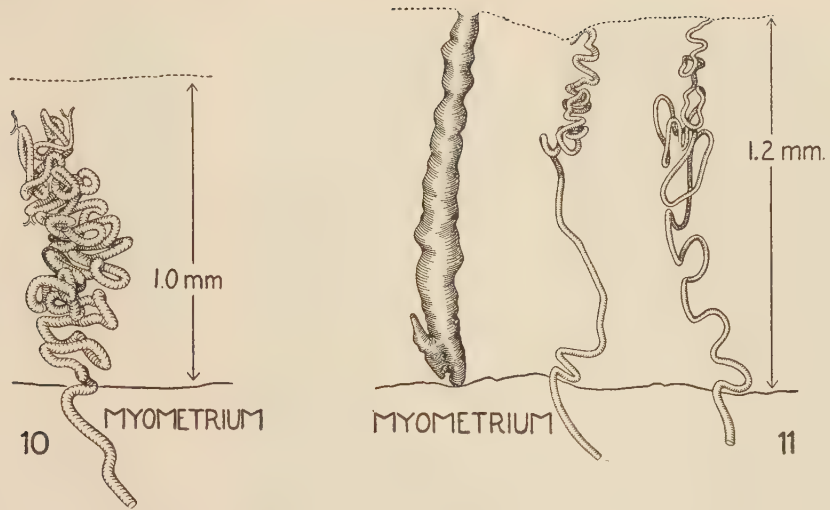


PLATE 6

EXPLANATION OF FIGURES

Photomicrographs ($\times 13$) of sections of corpus endometrium from ovulatory cycles. The arrows point to arterial fields.

- 14 Eighth day (no. 124); $8\ \mu$ section.
- 15 Eighth day (no. 132); $9\ \mu$ section.
- 16 Eleventh day (no. 111); $15\ \mu$ section.
- 17 Sixteenth day (no. 116); early pro gravid phase; $12\ \mu$ section.
- 18 Thirtieth day (no. 115); late pro gravid phase; $25\ \mu$ section.
- 19 Twenty-fourth day (no. 3); late pro gravid phase; $12\ \mu$ section.
- 20 Twenty-seventh day (no. 123); late pro gravid phase; $20\ \mu$ section.

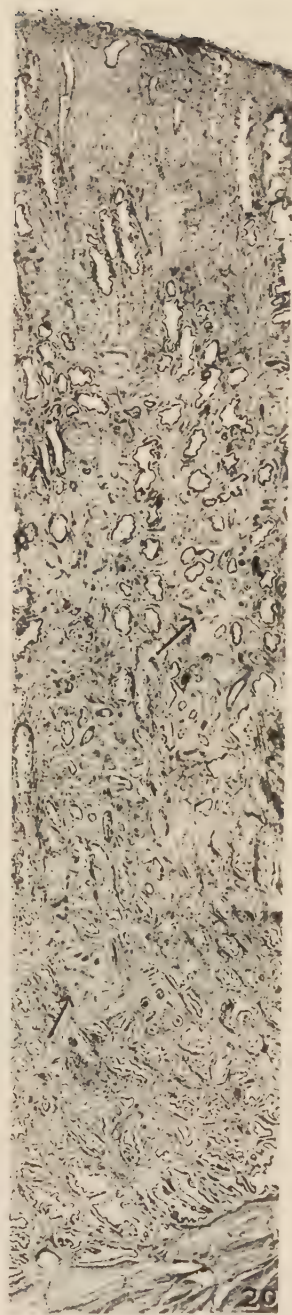
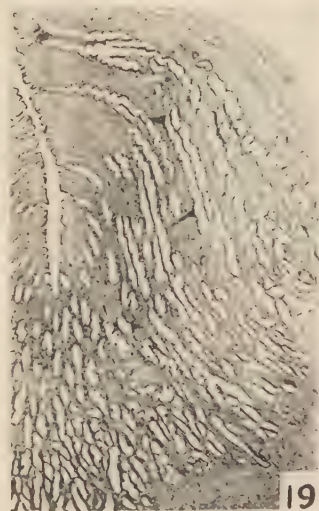
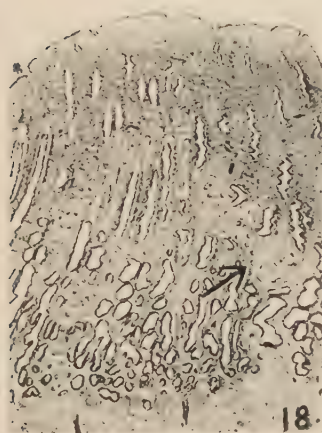
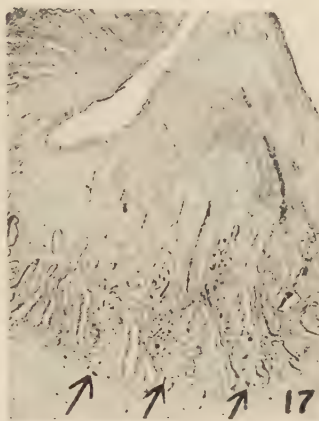
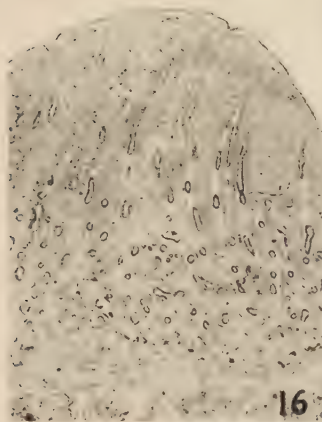
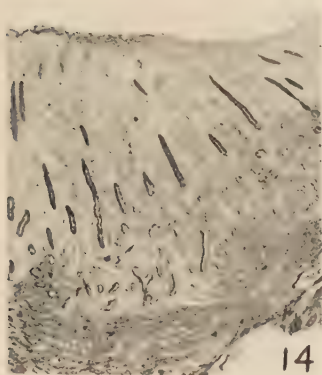


PLATE 7

EXPLANATION OF FIGURES

Photomicrographs ($\times 13$) of sections through corpus endometrium from anovulatory cycles.

21 Thirteenth day (no. 133); 15μ section. This may be an atypical specimen (compare p. 382).

22 Nineteenth day (no. 13); 12μ section.

23 Twenty-first day (no. 114); 15μ section. One ovary contained an atypical corpus luteum.

24 Twenty-sixth day (no. 17); 15μ section. One ovary contained a large cystic follicle. The arrow points toward an arterial field.

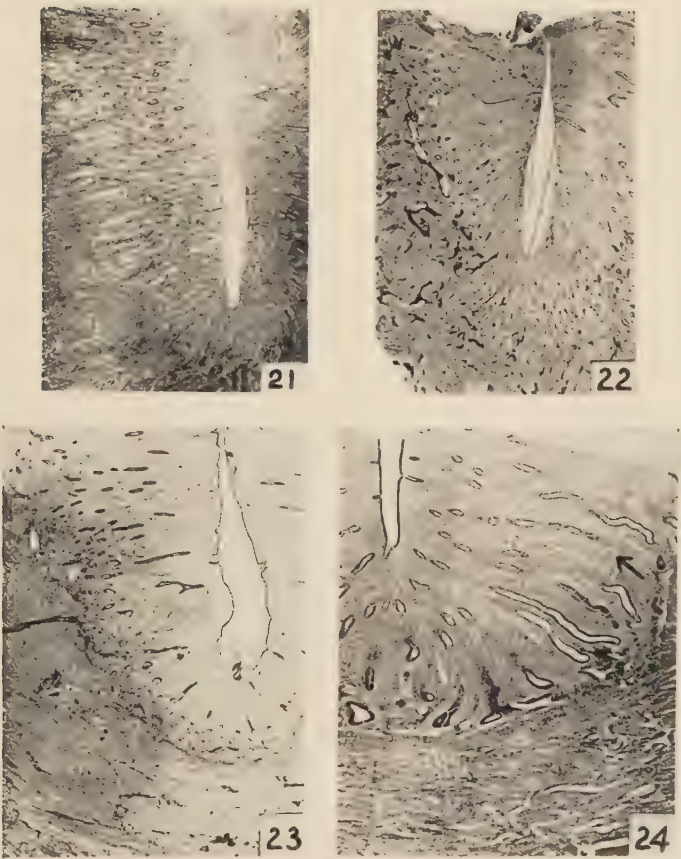


PLATE 8

EXPLANATION OF FIGURES

Photomicrographs ($\times 13$) of sections through corpus endometrium of uteri menstruating after ovulatory cycles.

- 25 Early first day (no. 122); $12\ \mu$ section.
- 26 First day (no. 127); $15\ \mu$ section.
- 27 Third day (no. 7); $12\ \mu$ section. Note the arterial fields in the desquamated tissue.
- 28 Second day (no. 121); $12\ \mu$ section.
- 29 Third day (no. 15); $12\ \mu$ section.
- 30 Third day (no. 20); $10\ \mu$ section.
- 31 Fourth day (no. 12); $8\ \mu$ section.
- 32 Fourth day (no. 120); early postmenstrual phase; $8\ \mu$ section.

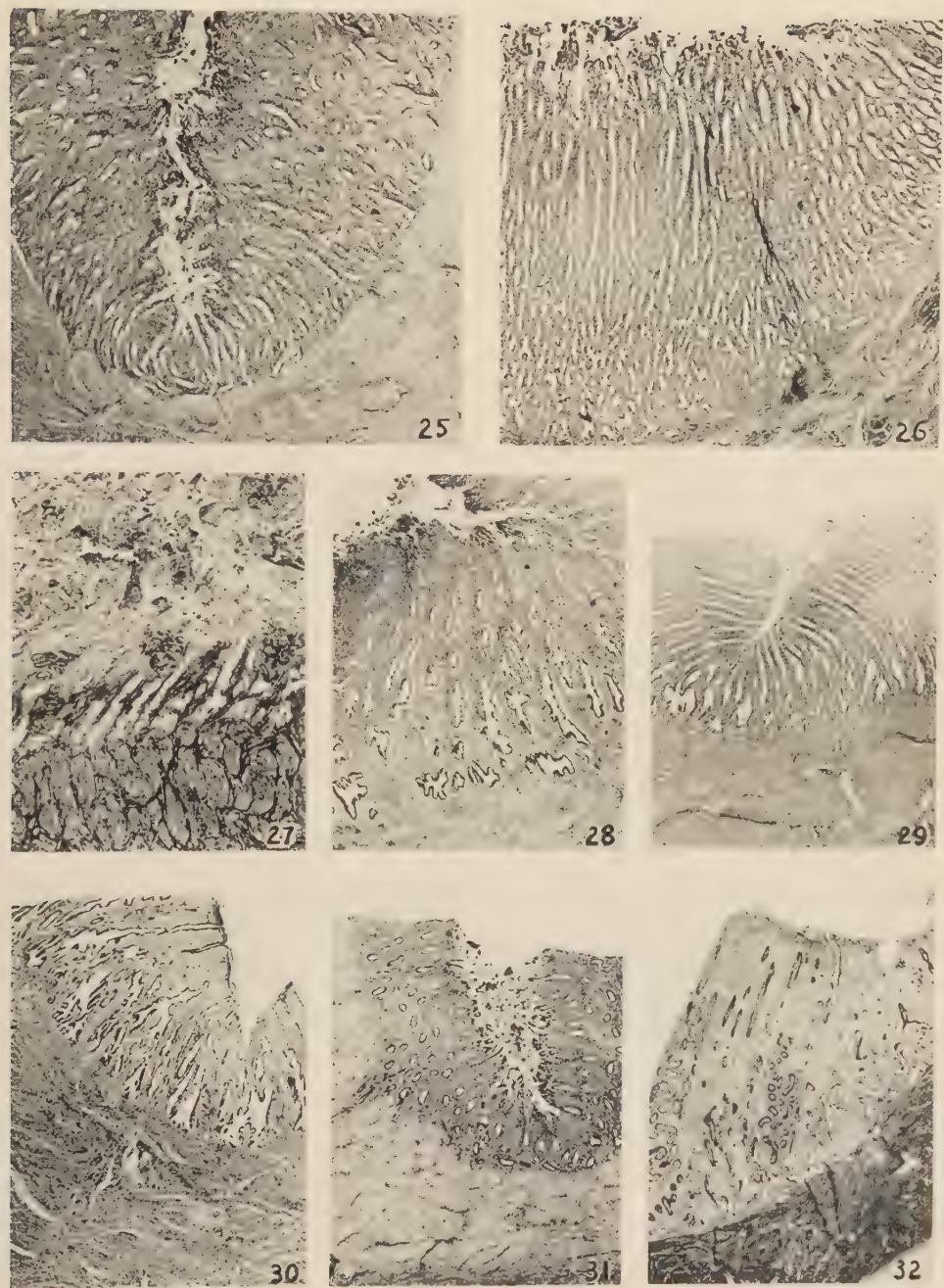


PLATE 9

EXPLANATION OF FIGURES

Photomicrographs ($\times 13$) of sections through corpus endometrium of uteri menstruating after anovulatory cycles.

- 33 Second day (no. 125); $15\ \mu$ section.
- 34 Second day (no. 113); $15\ \mu$ section.
- 35 First day (no. 135); $12\ \mu$ section.
- 36 Third day (no. 128); $8\ \mu$ section.

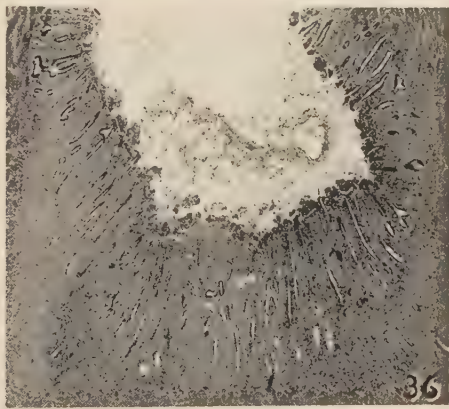
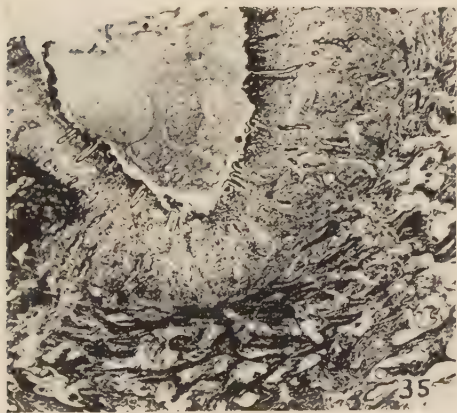
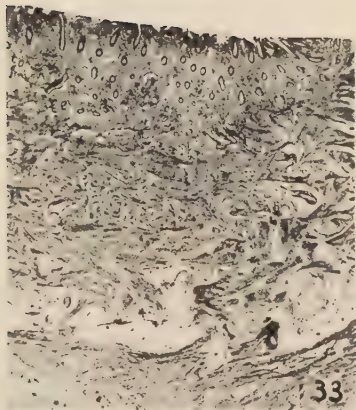


PLATE 10

EXPLANATION OF FIGURES

Photomicrographs of cleared, unstained, sections of corpora uteri from in vivo injected specimens.

37 Cross section, 0.2 mm. thick, through one-half of uterus showing coiled arteries of the endometrium. Eighth day (no. 124). $\times 10$.

38 Cross section, 0.2 mm. thick, showing coiled artery in pseudopregnant endometrium (compare fig. 5). Thirtieth day (no. 115). $\times 16.5$.

39 An 0.2 mm. section showing a radial, myometrial, artery extending from the stratum vasculare to the mucous membrane. At $\uparrow$ it enters the mucous membrane and becomes a coiled artery (undistinguishable here) such as those shown in figure 11. Note the tapering of the artery in the inner fifth of the myometrium. Second day (no. 113); menstrual phase; anovulatory cycle. $\times 34$.

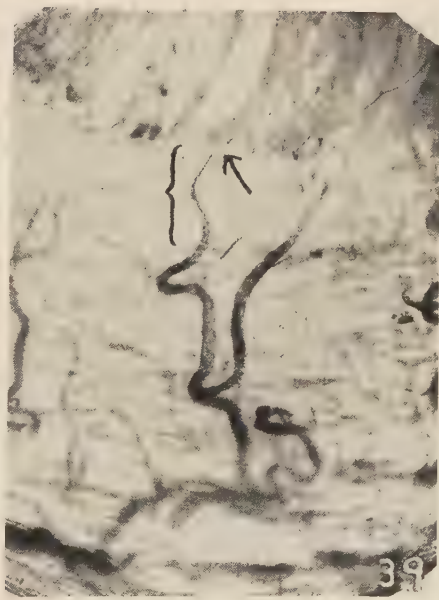
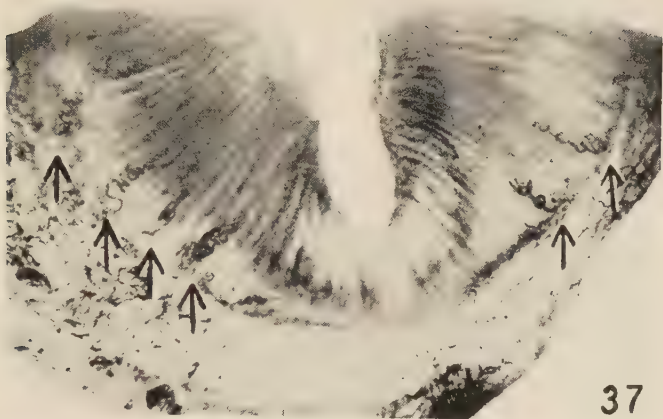


PLATE 11

EXPLANATION OF FIGURES

Photomicrographs of sections through corpus endometrium.

40 A section showing the disorganization of the wall of a coiled artery in the necrotic zone of a menstruating uterus (compare fig. 12; a reconstruction of a similar artery). Third day (no. 20); ovulatory cycle. Mallory's c.t. stain; 15μ section. $\times 100$.

41 A section similar to figure 40. The light area, at the arrow's point, is the end of the artery (on the right) in figure 11. Compare the organization of the arterial wall in the four successive coils seen. The black mass at the end of the artery is mercuric sulphide and blood. Second day (no. 113); anovulatory cycle. Mallory's c.t. stain; 15μ section. $\times 177.5$.

42 A section through the junction of the myometrium and mucous membrane showing a vein (V), and both types of endometrial arteries: type I (art. I) and type II (art. II). Sixteenth day (no. 116); ovulatory cycle. $\times 75$.

43 A section showing the proximity of the coiled arteries to the surface epithelium in the late pro gravid (pseudopregnant) phase. Twenty-fourth day (no. 3). Mallory's c.t. stain; 12μ section. $\times 100$.

